UNIT

C

# Environmental Chemistry

**In this unit, you will cover the following sections:**

## 1.0 The environment is made up of chemicals that can support or harm living things.

**1.1** Chemicals in the Environment

**1.2** Acids and Bases

**1.3** Common Substances Essential to Living Things

**1.4** How Organisms Take in Substances

## 2.0 The quantity of chemicals in the environment can be monitored.

**2.1** Monitoring Water Quality

**2.2** Monitoring Air Quality

**2.3** Monitoring the Atmosphere

## 3.0 Potentially harmful substances are spread and concentrated in the environment in various ways.

**3.1** Transport of Materials Through Air, Soil, and Water

**3.2** Changing the Concentration of Harmful Chemicals in the Environment

**3.3** Hazardous Chemicals Affect Living Things

**3.4** Hazardous Household Chemicals

# Exploring

Willow bark contains salicylic acid.

First Nations people relied on plants for both food and medicine.

## Medicine from the Environment

When you look at a willow like the one in the photo, you probably just see a tree or a bush. But when a pharmaceutical chemist looks at a willow, she sees an important chemical—salicylic acid. Chemists recognize that the environment is made up of chemicals. Some of these chemicals can interact to cure sickness and improve health in organisms.

First Nations people made use of chemicals in their environment for food and medicine. For example, they recognized the benefits of drinking willow bark tea. In Europe as well, willow bark had been used since at least 400 B.C. At that time, Hippocrates—now known as the Father of Medicine—had recommended it to treat pain and fever. The active ingredient in willow bark was identified in the 1800s as salicylic acid. In 1898, the Bayer company in Germany used a synthetic version of this chemical, called acetylsalicylic acid, to develop a new medicine under the brand name Aspirin.

Aspirin is just one of many medicines we use today that were originally derived from naturally occurring chemicals in the environment. Identifying plants that might provide such chemicals is challenging for scientists. The knowledge of local people helps them select the plants to test. Once the plants are collected, their chemical composition must be analyzed. Plants may be made up of hundreds of different chemicals. When a potentially useful chemical is found, it must be tested for safety and effectiveness.

Many people use an extract made from the purple coneflower *(Echinacea purpurea)* to help stimulate their immune systems. Echinacea is a traditional medicine in North America.

QUICK**LAB**

## Testing Health Products

Willow bark tea had an unpleasant side effect—it severely irritated the stomach and mouth. One of the tests that was done during the development of the commercial medicine was an acidity test. From other science classes, recall that litmus paper turns red in an acid and blue in a base. If there is no colour change, the test substance is said to be neutral. You will learn more about acids and bases as you work through this unit.

***Materials & Equipment***

- Aspirin suspension
- echinacea suspension
- vitamin C suspension
- antacid (e.g., Tums) suspension
- litmus paper
- spot plate
- medicine dropper

**Purpose**

To test some health products to determine if they are acidic, basic, or neutral

**Procedure**

1. Use the medicine dropper to place 5 drops of Aspirin suspension in a clean spot plate.
2. If you are using neutral litmus paper, dip one end of a small piece into the suspension in the spot plate. Record the results.
3. If you are using red and blue litmus paper, do step 2 first with red litmus paper. Then repeat step 2 using blue litmus paper.
4. Repeat steps 1 to 3 for each of the other suspensions. Make sure to use a clean medicine dropper and spot plate each time.

**Questions**

5. Which suspensions were acidic, basic, or neutral?
6. How do you know in each case?

## Focus On — Social and Environmental Context

While studying this unit, you will be asked to organize your thoughts about the chemical nature of the environment. As you work through the unit, think about the following questions:

1. **What chemicals do we find in the local and global environments?**
2. **How do changes in the concentration and distribution of these chemicals affect living things?**
3. **How can we assess the impact of our use of chemicals on the environment?**

The answers to these and other questions about environmental chemistry will help you understand the role of science and technology in monitoring and maintaining the environment.

# 1.0 The environment is made up of chemicals that can support or harm living things.

### Key Concepts

In this section, you will learn about the following key concepts:

- chemicals essential to life
- organic and inorganic material
- acids and bases
- ingestion and absorption of materials
- substrates and nutrients

### Learning Outcomes

When you have completed this section, you will be able to:

- describe processes by which chemicals are introduced into the environment
- identify acids, bases, and neutral substances based on measurement of their pH
- describe the effects of acids and bases
- identify common organic and inorganic substances that are essential to living things
- describe organic matter synthesized by organisms
- describe the uptake of materials by living things
- identify substrates and nutrient sources for living things in a variety of environments
- identify questions about the safe release of substances into the environment

Water is one of the chemicals that is essential for life. You can live only a few days without it. Life-supporting substances dissolve in water and are transported to all parts of your body. Water carries waste materials to your kidneys for removal.

A waterfall like the one shown here creates a large surface area exposed to the air. Gases such as oxygen that make up part of the air dissolve in the water. Aquatic plants, animals, and micro-organisms absorb the dissolved oxygen and use it to release energy through cellular respiration.

In this section, you will learn about chemicals in the environment. You will learn about natural and human processes that change the chemical composition of the environment. And you will learn how organisms use chemicals and are affected by them. You will investigate two important types of chemicals: acids and bases.

# 1.1 Chemicals in the Environment

Trees, mountains, the air we breathe, our own bodies—everything that makes up the environment is made of chemicals. All living things are made of chemicals and depend on chemicals to survive. Without carbon dioxide and water, green plants could not produce sugar for food. Without oxygen, plants and animals could not carry out cellular respiration. These are just a few of the chemicals that support living things.

Not all chemicals that form the environment support living things. For example, forest fires and volcanoes both release large quantities of chemicals such as carbon dioxide, sulfur dioxide, and ash. Even though these substances are produced naturally, they can be harmful to living things. Human activities can also cause chemical changes in the environment. We benefit from products such as gasoline, electricity, and pesticides, but by using them, we may be harming both the living and non-living environment.

**infoBIT**

**Volcanoes**

Volcanoes release 130 million tonnes of carbon dioxide into Earth's atmosphere every year.

## GIVE IT A TRY

### Chemicals in the Environment

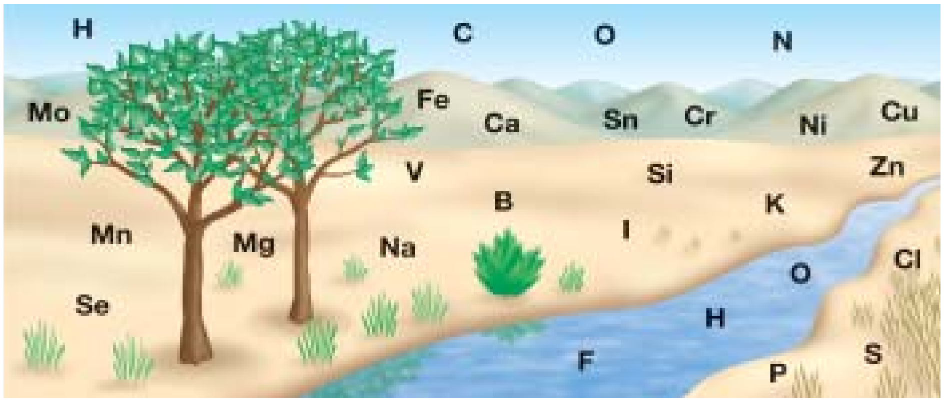



**Figure 1.1** Chemicals occur naturally everywhere.

Figure 1.1 is designed to give you an impression of the many elements that are important to life on Earth. These elements combine in different ways to form chemical compounds. **Elements** are pure substances that cannot be broken down into other substances.

- Select one of the symbols for the elements shown in Figure 1.1. Using the periodic table in Toolbox 12, record the name of the element.
- Use books, magazines, interviews, or electronic sources to find out how plants and animals use the element. Hint: An element may be used on its own or be part of a compound.
- If possible, also identify any beneficial and harmful effects of the element on living things, including humans.
- Record your findings on a poster.

TOOLBOX

## The Nitrogen Cycle

All chemical compounds are made up of elements. Recall that **elements** are pure substances that cannot be broken down into other substances. Also recall that some elements, such as oxygen and carbon, are always moving through ecosystems. They form chemical compounds that are used and reused by living things. Similarly, the chemical compound water changes state as it moves through ecosystems. The repeating changes of these elements and water as they move through ecosystems is called a cycle. The element nitrogen also cycles in this way.

### Nitrogen Fixation

Nitrogen is important for living things. For example, plants require nitrogen to make substances necessary for life. However, plants can use nitrogen only when it is combined with other elements, such as hydrogen and oxygen. Air is about 78% nitrogen in the form of nitrogen gas ($N_{2(g)}$). But plants can't use this "free" nitrogen directly. It has to be "fixed" in compounds with other elements. **Nitrogen fixation** is the process of changing free nitrogen so that the nitrogen atoms can combine with other elements to form compounds that organisms can use.

Certain types of bacteria do most of the nitrogen fixation in the soil. Some of these bacteria are located in the root nodules of specific types of plants, such as beans, clover, and alfalfa (Figure 1.2). The bacteria in these nodules are able to separate the two nitrogen atoms that form nitrogen gas (free nitrogen). Once separated, the nitrogen atoms can form compounds with other elements, such as hydrogen and oxygen. Lightning also converts nitrogen in the air to nitrogen compounds that plants can use.

**Figure 1.2** The bumps on the roots of this alfalfa plant are called "nodules." Bacteria in these nodules are able to fix nitrogen in the soil so other plants can use the nitrogen.

### Steps in the Cycle

After nitrogen fixation occurs, plants use the nitrogen-containing compounds. Animals then eat the plants. Their bodies use the nitrogen in the compounds to make more complex substances, such as proteins. Decomposers break down these large nitrogen-containing molecules in dead organisms and animal waste into simpler nitrogen compounds in the soil. The nitrogen can move from organisms and back to the soil several times. Eventually some nitrogen-containing compounds are broken down further by other bacteria in the soil. This nitrogen is released back into the air as free nitrogen, and the cycle begins again.

Figure 1.3 shows the nitrogen cycle. However, the concentration of usable nitrogen is not the same everywhere. This is similar to water. The total amount of water on Earth does not change, but too little water in some places causes droughts, and too much water causes floods. The concentration of usable nitrogen varies because it can be removed from the local environment in different ways. Conversion to free nitrogen by bacteria is one way. Another way is by water carrying dissolved nitrogen compounds away or deep into the soil so that they are unavailable to plants. Nitrogen is also lost in an area when plants are harvested. If soil lacks nitrogen, farmers plant nitrogen-fixing plants such as clover and alfalfa or add fertilizers to increase the amount of nitrogen.

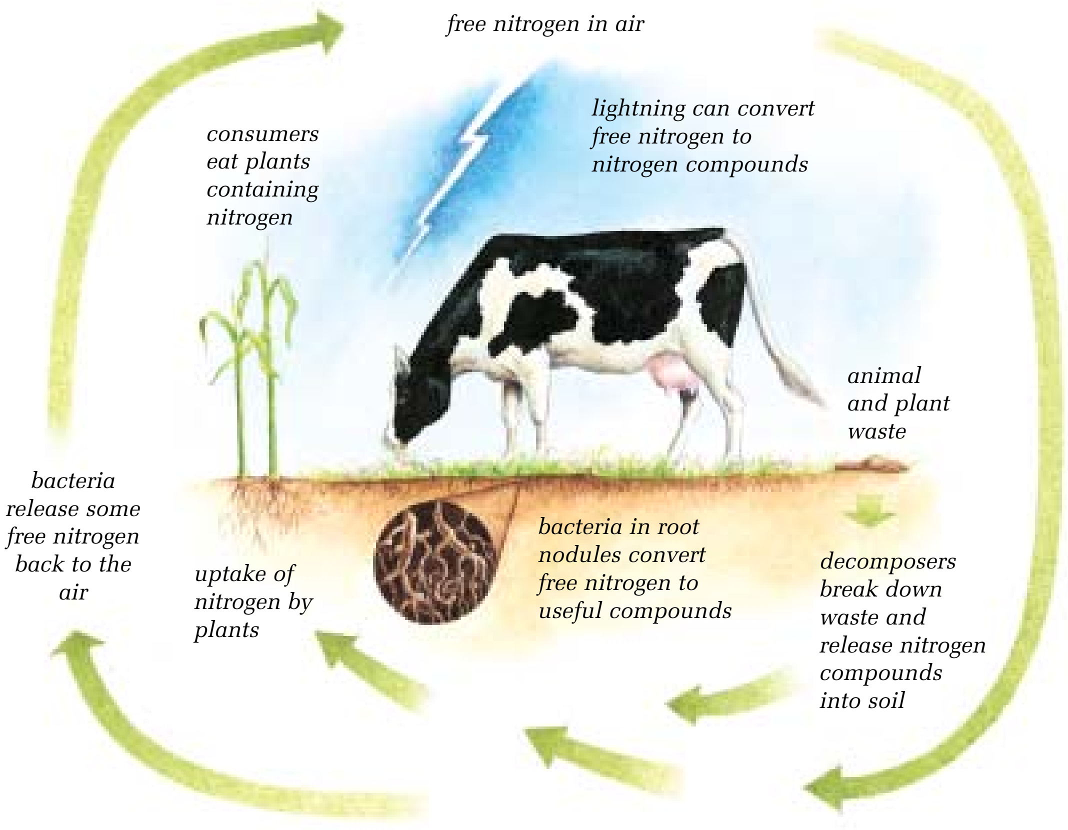



**Figure 1.3** The nitrogen cycle. Nitrogen moves from the air into the soil. Bacteria "fix" some of the nitrogen so it can be used by plants, while some is released to the air. This "fixed" nitrogen is taken in by plants, which may be eaten by animals. Plant and animal waste return nitrogen to the soil. The nitrogen may then be reused by plants or released to the air.

## Processes and Activities That Affect Environmental Chemicals

The nitrogen cycle is one example of how environmental chemicals change. Other processes and activities can also cause changes in the environment. Think about how you use and change chemicals.

Your body can be compared to a vehicle. You give it food as "fuel" and air rich in oxygen. It uses the chemicals in the food and the oxygen in the air in the process of cellular respiration to give you energy. One of the products you release in this process is carbon dioxide. When you travel in the family car or truck, the vehicle burns a fuel such as gasoline or propane. Oxygen from the air is required for that reaction. Along with the energy produced in this combustion reaction, gases such as water vapour, carbon dioxide, carbon monoxide, and nitrogen oxides are released into the atmosphere.

Cellular respiration is a natural process—a basic process that exists in nature. The nitrogen cycle is another natural process. Driving your car or truck is a human activity—an activity that humans design and carry out. Both natural processes and human activities may change chemicals in the environment. The chemicals formed by human activities are of special interest to many people who are concerned about pollution. **Pollution** is any change in the environment that produces a condition that is harmful to living things. For example, smog caused by vehicle exhaust emissions is pollution because it makes it hard for people and other animals to breathe. Forest fires produce similar chemical pollution.

## Human Activities

Human activities release chemicals into the air, water, and soil every day. Growing crops, disposing of solid waste, treating wastewater, manufacturing products, and driving vehicles are all examples of ways that we change the concentration of some chemicals in the environment. Many of these chemicals can be broken down through natural processes. Other chemicals cannot be broken down easily, and can cause long-term problems. Sometimes the use of chemicals becomes an issue. An **issue** is any subject of importance about which people have strong, conflicting points of view.

### Agricultural Activities


**Figure 1.4** This fertilizer contains the three elements nitrogen (15%), phosphorus (30%), and potassium (15%).

Farmers must have an understanding of chemistry to produce good crops. They have to know what chemicals to add to soil to improve plant growth and what chemicals to treat plants with to protect them from pests.

A **fertilizer** is a substance that enriches soil so that plants will grow better. For example, potassium is essential to plant growth. If a soil is low in potassium, plants cannot grow well in it. The soil must be enriched by adding a potassium fertilizer.

Fertilizers are described by the major nutrient elements they contain. These elements are nitrogen, phosphorus, and potassium. Figure 1.4 shows a typical fertilizer label. The three numbers 15–30–15 on the label indicate that this fertilizer contains 15% nitrogen compounds, 30% phosphorus compounds, and 15% potassium compounds. Some fertilizers have a fourth number and the letter "S" on the label to indicate that they contain sulfur as a major ingredient.

Fertilizers may come from natural sources or synthetic chemicals. They are added to the soil to help plant growth, but they must be applied carefully. It doesn't matter whether a fertilizer comes from a natural or a synthetic source—too much can damage organisms. Too much fertilizer may even damage the crop it's supposed to help. If fertilizer enters ponds, streams, lakes, or rivers, it may damage those ecosystems by changing the concentration of chemicals. You will learn more about the effects of fertilizers on water systems later in this unit.

Farmers also use their understanding of chemistry to apply pesticides safely. **Pesticides** are chemicals used to kill pests. A **pest** is an organism that harms people, crops, or structures. Pesticides are grouped according to the pest that they kill. Herbicides kill or control weeds. Insecticides kill or control insects. Fungicides kill fungi.

**Figure 1.5** Some types of insects damage or destroy food crops. The bertha armyworm shown here is a major pest of canola.

It is estimated that at least 50% of the world's food production would be lost to pests if pesticides were not used. However, improper application of pesticides can be harmful to people and other non-pest organisms. Pesticides can also create other problems.

Some pesticides are not selective—they kill both pest and non-pest species. For example, the bertha armyworm shown in Figure 1.5 is a pest of canola. Spraying for the armyworm may kill bees, which are important for pollinating canola and other crops. Another problem occurs with pesticides that stay in the environment for a long time. For example, DDT lasts from 2 to 15 years. It is not approved for use in North America, but it is still used in some parts of the world to kill mosquitoes that carry the disease malaria. Some pests become resistant to pesticides, so new pesticides must be developed to control them.

### Solid Wastes

Chemicals may be introduced into the environment when we dispose of solid waste or wastewater. Solid waste includes the garbage that is collected from households, industrial plants, commercial buildings, institutions, and construction and demolition sites. It includes large items, such as machinery, all the way down to small items, such as the caps on plastic drink bottles.

Some solid waste can be reused or recycled, but most of it is placed in landfill sites, like the one in Figure 1.6. Some hazardous wastes are burned in special plants called incinerators, which burn at very high temperatures. Emissions from incinerators may contribute to air pollution.

Sanitary landfill sites are specially built to prevent waste chemicals from moving into the soil. As rainwater or groundwater moves through solid waste, it can dissolve or corrode some items. Sanitary landfills use plastic liners and compacted clay to prevent these solutions from entering the soil and the groundwater.

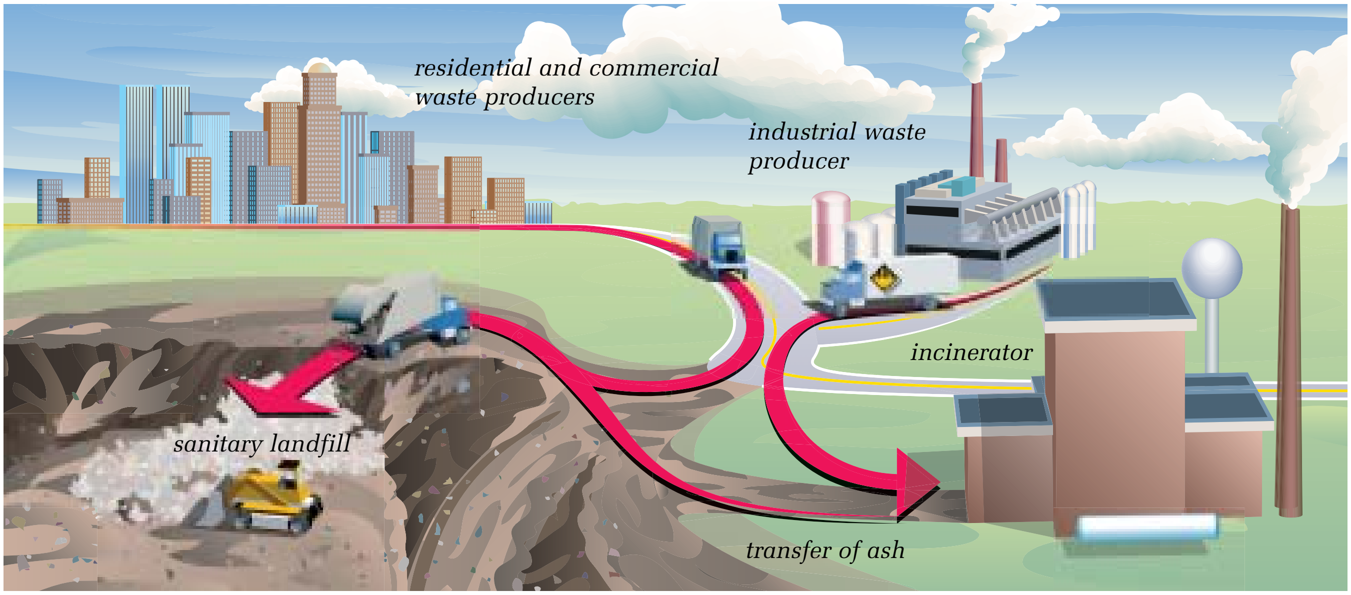



**Figure 1.6** In a sanitary landfill, wastes are spread and compacted by bulldozers before they are covered by a layer of soil.

**Figure 1.7** The soap and dirt from this car flow into the storm drains in the street. From there, the water flows into local rivers or lakes.

### Wastewater

Wastewater containing dissolved and undissolved materials from your kitchen, bathroom, and laundry is called **sewage**. Sewage moves through pipes into a septic tank in rural areas or to a sewage treatment plant in towns and cities. A **septic tank** is an underground container where bacteria break down the organic materials before they are moved out to the soil. A **sewage treatment plant** treats wastes from homes, businesses, industries, and institutions. It may also treat water from street drains. Treated wastewater or **effluent** is released into rivers or lakes. It may contain nitrogen and phosphorus from the breakdown of sewage during treatment.

If the municipal sewage system cannot handle a large quantity of rain water from street drains, that water may go directly into a river or lake through large pipes called **storm sewers**. Water from storm sewers contains chemicals washed off the street, such as oil or other fluids that have leaked from vehicles, and salt from snow-clearing operations.

### Fuel Combustion

Coal, oil, and natural gas are called **fossil fuels** because they formed from dead plants and animals. They are called hydrocarbons because they are mainly made up of the elements hydrogen and carbon. They may also contain oxygen, nitrogen, and sulfur. Fossil fuels may contain traces of other elements such as mercury and lead.

When fossil fuels are burned in homes, vehicles, and industrial plants, they produce large amounts of carbon dioxide and water vapour. The general reaction equation for this combustion reaction is:

$$\text{hydrocarbon} + \text{oxygen} \longrightarrow \text{carbon dioxide} + \text{water} + \text{energy}$$

The combustion of fossil fuels may also release pollutants such as sulfur dioxide, nitrogen oxides, and traces of mercury and lead into the air.

The equations below show what happens in the combustion of methane (in natural gas) and propane. Propane is used in barbecues, vehicles, and some home appliances.

$$CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(g)}$$

methane + oxygen ⟶ carbon dioxide + water vapour + energy

$$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

propane + oxygen ⟶ carbon dioxide + water vapour + energy

As consumers, we are most familiar with the fuels from crude oil and natural gas, which we use in our homes and vehicles. At one time, coal was also used in homes as a heating fuel. Today it is used mainly for electrical generation.

ACTIVITY C-1

**Decision Making**

# VIEWPOINTS ON ELECTRIC POWER

### The Issue

Alberta needs more power for its growing economy and increasing population. How can scientific questions be used to help people decide how this power should be generated?

### Background Information

1. At large electric power plants, turbines (large wheels) turn coils of wires or magnets in a generator to produce electricity. Hydro-electric plants use falling water to turn the turbines, and wind-powered plants use windmills. Where falling water or wind are not available, water is converted to steam by burning a fossil fuel such as coal, natural gas, or oil. The steam turns the turbine.
2. Consider the following viewpoints:
   a) “Alberta has a lot of low-sulfur coal. Natural gas is in much more limited supply. If we use natural gas to produce electricity, we won’t have as much available for making plastics. Let’s use the coal to produce inexpensive electricity.”
   b) “Natural gas is the cleanest burning fuel. We will have fewer environmental problems in the future if we build plants that burn natural gas.”
   c) “Burning fossil fuels produces harmful chemicals such as sulfur dioxide, nitrogen oxides, and mercury. I like the idea of using windmills to generate electricity. It might be less efficient than burning coal or natural gas, but it is the most environmentally friendly method.”
   d) “Any method is fine as long as the amount of harmful substances released from the electrical plants into the atmosphere does not exceed the government standards.”

### Analyze and Evaluate

TOOLBOX

3. What viewpoint is expressed by each speaker in step 2? (Use Toolbox 4, to help you identify viewpoints. You may find more than one viewpoint per speaker.)
4. Imagine that you can talk to the speakers. List five questions you might ask them. Compare your questions to those asked by your classmates.
5. Science attempts to understand and explain the natural world. Identify any two of your questions that might be answered by scientific knowledge or processes. Explain why you chose these questions.
6. Technology involves the designing and building of things that satisfy human needs and wants. Identify one question that might be answered by technological knowledge or technological development. Explain why you chose this question.

**Figure 1.8** Sheerness Generating Station, east of Drumheller, uses coal to generate electricity.

## reSEARCH

**Electricity Generation in Alberta**

Research one way that electricity is generated in Alberta. Explain the electricity generation process you chose. In a T-chart, list its advantages and disadvantages. Begin your information search at www.pearsoned.ca/ scienceinaction.

### Industrial Processes

Industrial processes such as electrical power generation, mineral processing, and fertilizer production may release chemicals into the air. A common industrial process in Alberta is natural gas processing. Natural gas is composed of compounds such as methane, ethane, propane, and butane. It also contains nitrogen gas, carbon dioxide, hydrogen sulfide, helium, and traces of metals such as mercury.

Natural gas is processed to separate its components for different uses. Methane, propane, and butane are all derived from natural gas and are used primarily for heating. Ethane is used in plastics such as polyethylene.

Natural gas is also processed to eliminate unwanted substances such as hydrogen sulfide, a poisonous chemical. Natural gas that contains hydrogen sulfide is called **"sour" gas**. If no hydrogen sulfide is present, the gas is considered "sweet."

The process for removing hydrogen sulfide produces sulfur dioxide gas and pure sulfur. Since the 1970s, natural gas processing plants in Alberta have been required by law to restrict their sulfur dioxide emissions. They now recover more than 99% of the pure sulfur for use in manufacturing sulfuric acid. Sulfuric acid is used in making fertilizers, steel, synthetic fibres, and paints.

## Check and Reflect

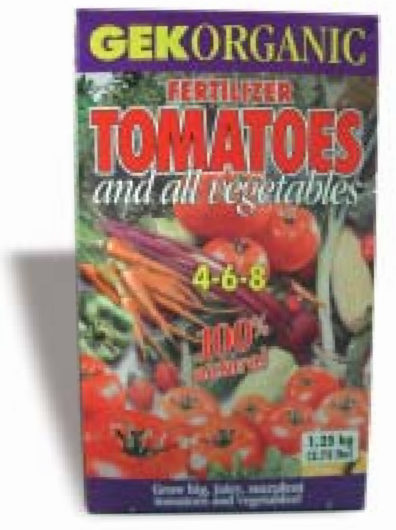



**Figure 1.9** Fertilizer label for question 3

### Key Concept Review

1. What role do decomposers play in the nitrogen cycle?
2. What is pollution? Give three examples of chemical pollution.
3. What do the numbers on the fertilizer label in Figure 1.9 indicate?
4. Define the term "herbicide."
5. How do sanitary landfill sites prevent chemicals from moving into the groundwater?

### Connect Your Understanding

6. Describe two ways that nitrogen is removed from an ecosystem.
7. What pollutants are released from fossil fuel combustion?
8. Why do farmers use fertilizers?
9. Why does sewage need to be treated?

### Extend Your Understanding

10. Suggest two ways that you could reduce your need for a fuel-burning vehicle.
11. Identify two issues related to human activities that change chemicals in the environment. For each one, explain why it is considered to be an issue.

# 1.2 Acids and Bases

In earlier studies, you may have learned that acid rain can be harmful to both the living and non-living environment. An **acid** is a compound that dissolves in water to form a solution with a pH lower than 7. The **pH** number of a solution indicates its acidity. It is a measure of the concentration of hydrogen ions in a solution.

Industrial processes and fuel combustion produce large quantities of carbon dioxide, sulfur dioxide, and nitrogen oxides. In the air, these chemicals dissolve in water droplets to form acids. Sulfur dioxide combines with water to form sulfuric acid. Nitrogen oxides combine with water to form nitric acid. Carbon dioxide dissolves in water to form carbonic acid. All these droplets then fall as acid rain. Acid rain is a concern around the world for several reasons. It can cause lakes and streams to become acidic, which harms the organisms that live in them. It can increase the rate at which buildings and monuments deteriorate.

Acid rain is harmful to the environment, but acids can also be beneficial. Vinegar, for example, is a dilute solution of acetic acid. Lemon juice contains citric acid. Some types of plants, such as blueberries, grow better in acid soils.

A **base** is a compound that dissolves in water to form a solution with a pH higher than 7. Hair conditioner is a base, as are many household products.

**infoBIT**

**Natural Acid**

The sting of the bite from a red ant is partly caused by formic acid. At one time, the bodies of red ants were used to produce large quantities of formic acid for use in dyeing wool and tanning leather. Today synthetic formic acid is used.

## pH Scale

Acidity is measured according to the pH scale. Most solutions have a pH in the range of 0 to 14. A solution with a pH of 0 is very acidic. For example, battery acid has a pH of about 0.5. A solution with a pH of 14 is very basic or alkaline. For example, household ammonia has a pH of about 12.6. A pH of 7 means that a solution is **neutral**—it's neither an acid nor a base.

The difference between one number and the next on the pH scale represents a 10-fold difference. For example, a solution with a pH of 3 is 10 times more acidic than a solution with a pH of 4. Similarly a solution with a pH of 9 is 10 times more basic than a solution with a pH of 8.

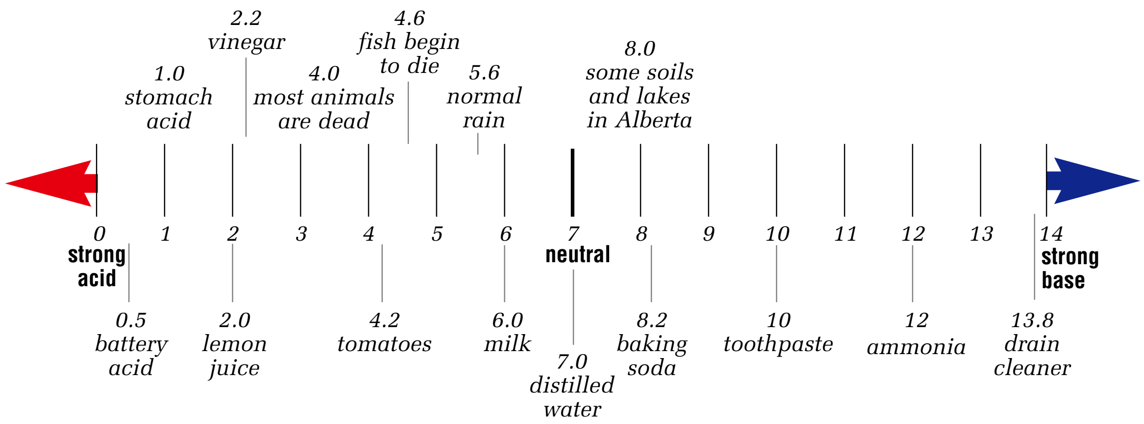



**Figure 1.10** This figure shows the pH measurements of some common household products and some environmental situations.

Activity C-2

Inquiry

# Measuring Acids and Bases

### Materials & Equipment

- pH meter, chemical indicators, or pH paper
- distilled water
- small beakers
- materials to be tested (e.g., local water, pure water, rain or melted snow, household ammonia, vinegar, lemon juice, antacid tablet dissolved in water, baking soda solution, carbonated drink, fruit juices)
- 5-mL measuring spoon

**Caution!**
Acids and bases can burn the skin and eyes. If any of the ingredients spill, wash immediately with cold water. Never mix substances (unless you are told to) since they may react and produce dangerous chemicals.

**Caution!**
Make sure the room is well ventilated when you test ammonia.

## Before You Start

In this activity, you may use either a pH meter, chemical indicators, or pH paper to determine the pH of substances. The pH meter shows the pH of the substance being tested. For chemical indicators and pH paper, a colour guide will help you measure the pH of acids and bases.

## The Question

What are the pHs of some common substances?

## Procedure

1. Place 10 mL of each solution in separate beakers.
2. If you are using a pH meter, rinse the meter's probe with distilled water. Submerge the tip of the probe in one of the solutions. Read and record the pH. Repeat for each solution.
3. If you are using a chemical indicator, place several drops of the chemical indicator in each solution. Observe and record the colour. Use the colour guide to determine the pH. Record the pH.
4. For pH paper, use a clean strip for each solution. Dip the end of the pH paper into the solution. After about 2 s, remove the paper. Compare the colour of the wet end of the paper with the colour guide. Record the pH.

**Figure 1.11** You can use a pH meter, chemical indicators, or pH paper for this activity.

## Analyzing and Interpreting

5 Which is the manipulated variable and which is the responding variable in this activity?

6 Describe how you determined the pHs of the substances tested.

## Forming Conclusions

7 a) Which solutions were acids? How do you know?
b) Which solutions were bases? How do you know?
c) Which ones were neutral? How do you know?

## MEASURING PH

You can use a pH meter or acid-base indicators to measure pH. A pH meter consists of a probe attached to a meter. To test a fluid, you submerge the tip of the probe in it, and the meter indicates the fluid's pH.

Acid-base indicators are substances that can change colour when they are placed in solutions. For example, blue litmus paper turns red in an acid, and red litmus paper turns blue in a base. A universal indicator is a mixture of indicators that change colour over a wide pH range. The pH of a clear fluid can be identified by the colour of the fluid after several drops of the indicator have been added. To determine the pH, you need to use a colour chart to compare the colour of the test fluid with that of a known standard.

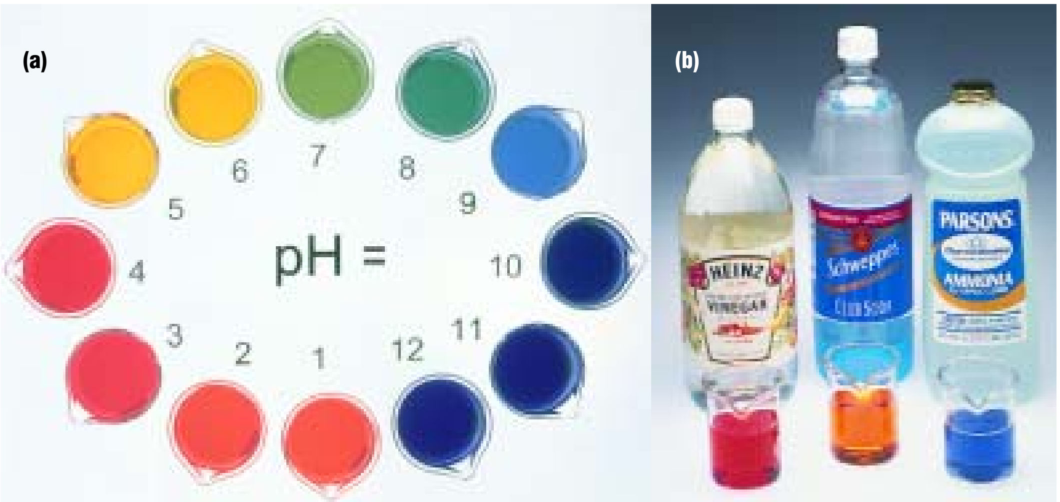



**Figure 1.12** (a) You can determine the pH of a solution with a universal indicator by comparing the colour of the solution with a colour chart. (b) Compare the colour of these solutions with the standard ones shown in (a) to determine the pH of each of these common household solutions.

## NEUTRALIZATION

If you have an upset stomach, you might take an antacid to help you feel better. An antacid is a mild base that reacts with the acid in your stomach to neutralize it. The base in the antacid and the acid in your stomach react to form compounds that are less upsetting to your stomach. This acid-base reaction is called **neutralization**. The neutralization reaction produces water and a compound called a **salt**. For example, what we call table salt can be produced by combining hydrochloric acid with sodium hydroxide solution, a base. Here is the equation for that neutralization reaction:

$$\begin{array}{ccccccc} HCl_{(aq)} & + & NaOH_{(aq)} & \longrightarrow & NaCl_{(s)} & + & H_2O_{(l)} \\ \text{acid} & + & \text{base} & \longrightarrow & \text{salt} & + & \text{water} \end{array}$$

Earlier in this subsection, you learned that a neutral solution is one with a pH of 7—it's neither acidic nor basic. That means that it doesn't have the properties of acids or bases, which sometimes can be harmful to humans and the environment. For example, if a strong base spills from a tanker truck, a weak acid can be used to neutralize it.

Activity C-3

Inquiry

# Neutralizing Acid

## The Question

What effect does adding a base to an acid have on the pH of a solution?

## The Hypothesis

Reword the question in the form of a hypothesis.

### *Materials & Equipment*

- baking powder
- water
- graduated cylinder
- 2 50-mL beakers
- vinegar
- pH meter, chemical indicators, or pH paper
- 2-mL measuring spoon

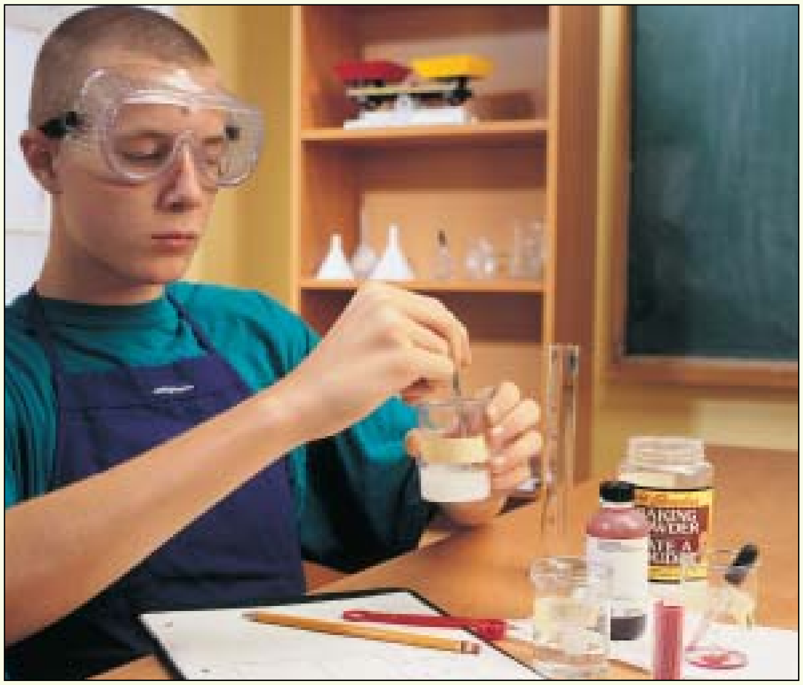


**Figure 1.13** Step 3

## Procedure

1. Place 2 mL of baking powder in 30 mL of water in a 50-mL beaker. Test and record the pH of the baking powder–water mixture.
2. Place 10 mL of vinegar in another 50-mL beaker. Test and record the pH of the vinegar.
3. Stir the baking powder mixture. Slowly stir 10 mL of this mixture into the vinegar in the beaker. Measure and record the pH of the vinegar–baking powder mixture.

## Analyzing and Interpreting

4. Was the pH of the vinegar–baking powder mixture different from the pH of the vinegar alone? Explain your answer.
5. What evidence was there that a chemical reaction took place?
6. Was your hypothesis correct? Why or why not?

## Forming Conclusions

7. Describe the effect that adding a base to an acid has on the pH of the solution.

## Extending

Design and carry out an experiment to determine how adding water to a solution affects its pH.

## Neutralizing the Effects of Acid Rain

At the beginning of this subsection, you read about the formation of acid rain. Ordinary rainwater is naturally slightly acidic. The raindrops dissolve carbon dioxide from the air to form very weak carbonic acid, which has a pH of about 5.6. In some areas of Canada, mainly in central Canada, acid rain has a pH as low as 3. In earlier studies, you may have learned about the effects of acid rain on living things and buildings. Many lakes in Ontario and Quebec became so acidic that organisms could no longer survive in them.

Acidic lakes are sometimes treated with lime (calcium hydroxide) to neutralize them. The lime is mixed with water so that it dissolves. A chemical reaction takes place between this limewater, which is a base, and the dilute sulfuric acid of the lake's water. The reaction produces calcium sulfate (a salt) and water. If all the acid and all the base are used up, the solution becomes neutral. The equation for that reaction is:

$$Ca(OH)_{2(aq)} + H_2SO_{4(aq)} \longrightarrow CaSO_{4(s)} + 2H_2O_{(l)}$$

calcium hydroxide + sulfuric acid ⟶ calcium sulfate + water

You will learn more about the effects of acids and bases on living things as you work through this unit.

**reSEARCH**

**Acid Effects in the Canadian Shield**

The Canadian Shield is a large horseshoe-shaped area of ancient rocks around Hudson Bay. It covers much of eastern and central Canada. Using books or electronic resources, explain in a paragraph why the water bodies on the Canadian Shield are so sensitive to acidic deposition. Begin your information search at www.pearsoned.ca/scienceinaction.

## Check and Reflect

### Key Concept Review

1. Define the terms "neutral solution," "acid," and "base."
2. State whether each sentence below refers to an acid, a base, or a neutral solution.
   a) Solution A turns blue litmus paper red.
   b) Solution B has a pH of 10.
   c) Pure water has a pH of 7.
   d) Solution C neutralizes an acid.

### Connect Your Understanding

3. a) List three human activities that release chemicals that produce acid rain.
   b) Identify the chemicals that are released and the acids they form.
4. What is the scientific meaning of the following sentence? *Lemon juice is an acid.*
5. You have been asked to determine the pH of a solution. Explain why using a pH meter or a universal indicator is better than using litmus paper.

### Extend Your Understanding

6. Predict what the chemical products will be if sulfuric acid ($H_2SO_{4(aq)}$) and sodium hydroxide ($NaOH_{(aq)}$) are mixed together.
7. Suppose that there is a small lake on property that you own. The pH of the water in the lake has increased to 8.1 because of human activities.
   a) How could you make the water neutral?
   b) What environmental changes might you expect following the neutralization of the lake water?

# 1.3 Common Substances Essential to Living Things

**Figure 1.14** Composition of the human body: water, proteins, fats, sugars, starch, DNA, minerals, vitamins, salts, acids, and bases

Our bodies need about 25 elements for normal growth. The chemical symbols for these elements are shown in Figure 1.1 at the beginning of subsection 1.1. Carbon (C), oxygen (O), and hydrogen (H) are the most common chemical elements in living things. Together, they make up the complex molecules that form sugar, starch, fat, oil, wax, and proteins. Because these complex molecules contain carbon, they are called **organic compounds**. Fossil fuels (petroleum, natural gas, and coal) are examples of substances that contain many different organic compounds. Substances that do not contain carbon are called **inorganic compounds**. Baking soda and the mineral quartz are examples of inorganic compounds.

Organic molecules can be very large and complex. On Earth, these molecules far outnumber inorganic molecules.

## *GIVE IT A* **TRY**

### ORGANIC OR INORGANIC?

Draw a table with two columns. List the following items in the left column: oxygen, distilled water, sugar, motor oil, hydrochloric acid, rust, vitamin C, glass, fat, rubber.

In the right column, identify each item as organic or inorganic.

## Macronutrients

All living things need nutrients to survive. **Nutrients** are elements and compounds that organisms need for living, growing, and reproducing. Plants obtain the nutrients carbon, hydrogen, and oxygen from air and water. They obtain nitrogen, phosphorus, potassium, magnesium, calcium, and sulfur from the soil. These nine elements are all essential for the normal growth of plants. Because they are needed in relatively large amounts, they are called **macronutrients** ("macro-" means large or large scale). In earlier science classes, you learned about the importance of carbon, hydrogen, and oxygen for living things. You will learn more about them throughout this unit. The table below summarizes the role of the six other macronutrients in the growth and development of plants and humans.

Elements such as selenium are also essential for plant and animal growth and development. However, they are needed in only minor or trace amounts, so they are called **micronutrients** ("micro-" means very small or small scale).

### *info*BIT

**Elements in the Human Body**

Just six elements—oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus—make up 99% of the human body.

| Nutrient | In plants, it's important in: | In humans, it's important in: |
|---|---|---|
| Nitrogen (N) | • Composition of proteins and chlorophyll<br>• Leaf and stem growth | • Composition of proteins and nucleic acids found in all cells<br>• Growth and repair of tissues |
| Phosphorus (P) | • Root and flower growth<br>• Cellular respiration and photosynthesis | • Composition of bones, teeth, and DNA<br>• Many metabolic reactions |
| Potassium (K) | • Stimulation of early growth<br>• Starch and protein production and sugar movement<br>• Disease resistance<br>• Chlorophyll production and tuber formation | • Muscle contraction and nerve impulses |
| Magnesium (Mg) | • Composition of chlorophyll structure<br>• Photosynthesis | • Composition of bones and teeth<br>• Absorption of calcium and potassium |
| Calcium (Ca) | • Cell wall structure<br>• Cell division | • Composition of bones and teeth<br>• Blood clotting<br>• Muscle and nerve function |
| Sulfur (S) | • Production of fruits and grains | • Protein synthesis<br>• Enzyme activation<br>• Detoxification |

**Figure 1.15** Knowledge of how elements are used by plants can help farmers diagnose problems like those shown here.

## Maintaining the Right Level of Nutrients

Knowing how plants use elements can help farmers diagnose deficiencies and excesses of nutrients in the soil. Consider this scenario. A farmer has noticed that his crops are not growing as well as they have in past years. The lower leaves on the plants are showing a distinct yellow striping, and the plants are not as tall as they should be. The farmer has been applying large amounts of phosphorus and potassium fertilizer, expecting to get high yields from the crops.

Soil tests show low levels of magnesium and high levels of potassium. The farmer knows that high levels of potassium can interfere with the absorption of magnesium by the plant. One solution is to stop applying potassium fertilizer, since the soil has an adequate supply already, and apply a fertilizer containing magnesium.

## Optimum Amounts

In the early 1980s, a reservoir was built in California to control the flow of irrigation water to farms. Shortly after the reservoir was built, many fish in the reservoir died. Birds living on or near the reservoir were also dying or producing abnormal chicks. Tests showed that the surviving fish contained a high level of selenium. Birds' eggs from the area contained eight times more selenium than similar eggs 10 km away. The selenium was traced back to soils around the reservoir.

The micronutrient selenium is an element that is required in trace amounts in your diet. Too much of it can cause harmful health effects, like those that affected the wildlife around the California reservoir. But too little selenium can also be harmful to your health. If plants are deficient in selenium, the animals that eat them will also have a deficiency of selenium. Scientific studies have shown that selenium deficiency in humans can be linked to diseases such as cancer and heart disease. Selenium, along with vitamin E, helps to protect cell membranes from damage caused by hydrogen peroxide, a poison that is produced in some chemical reactions in cells.

Selenium, like most other substances, should be available in our diets in **optimum amounts**. The optimum amount of a substance is the amount that provides an organism with the best health. For humans, at least 70 μg (micrograms) of selenium per day is recommended.

**Figure 1.16** The far right is the foot of a healthy pig. The other two feet belong to pigs that have ingested too much selenium.

## Types of Organic Molecules

Most chemicals in humans and other living things are organic compounds. Four important classes of organic compounds are: carbohydrates, lipids, proteins, and nucleic acids.

**Figure 1.17** Carbohydrates are a major part of our diet.

### Carbohydrates

When we eat food such as pasta, rice, potatoes, fruits, and bread, we are eating carbohydrates. **Carbohydrates** are organic molecules made up of atoms of carbon, hydrogen, and oxygen. These atoms can form simple molecules, such as sugar, or large, complex molecules, such as starch, cellulose, and glycogen.

Glucose is the simple sugar made by green plants in photosynthesis. The atoms in a molecule of glucose usually join together to form a six-sided figure as shown in Figure 1.18(a). Complex carbohydrates such as cellulose, starch, and glycogen are composed of many glucose molecules joined together, as shown in Figure 1.18(b).

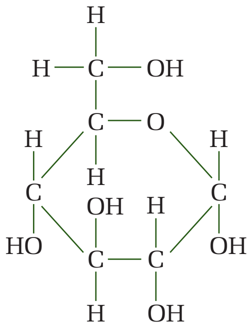


**Figure 1.18(a)** A glucose molecule has the formula $C_6H_{12}O_6$.

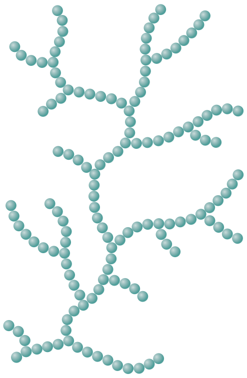


**Figure 1.18(b)** A glycogen molecule is made up of connected glucose molecules. Each circle represents a glucose molecule.

### Lipids

Fats, oils, and waxes are **lipids**—compounds composed of many carbon, hydrogen, and oxygen atoms. Both animals and plants produce lipids. For example, our skin produces oils, and our bodies store food in the form of fat. Plant products such as canola seeds, corn, peanuts, soybeans, walnuts, and cashews contain large amounts of oils.

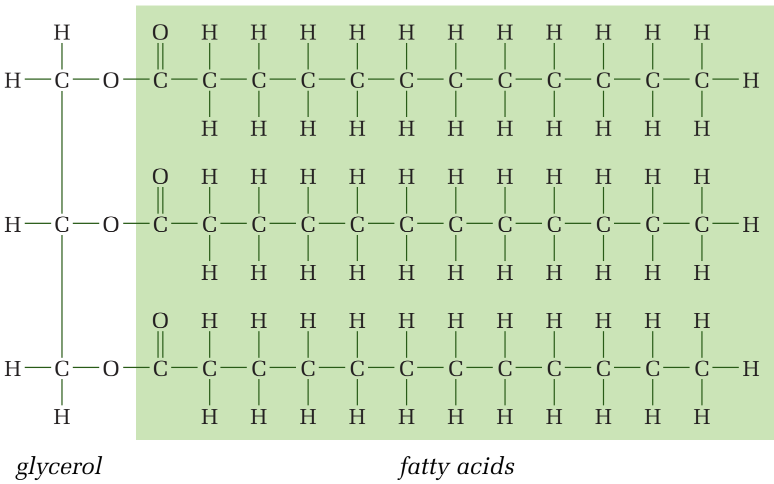



**Figure 1.19** A fat molecule is made up of three chains of fatty acids connected to one molecule of a compound called glycerol.

Activity C-4

Inquiry

# Testing for Organic Molecules

## The Question

How can indicators be used to test for the presence of different organic molecules?

***Materials & Equipment***

- substances to be tested (glucose/dextrose solution, corn starch mixed in water, vegetable oil, gelatin solution)
- water
- Benedict's solution
- Biuret solution
- iodine solution
- spot plate
- brown paper
- medicine droppers
- test tubes
- hot water bath
- stir sticks
- test tube containing unknown substance(s)

**Caution!**
Benedict's solution, Biuret solution, and iodine solution are hazardous, corrosive substances that can stain your clothes and skin. Handle them carefully.

**Caution!**
Hot water scalds and hot surfaces burn.

**Figure 1.20** Step 6

## Procedure

1. In this activity, you will be testing for different types of organic molecules. This table shows the indicators you will use.

| Substance | Test |
|---|---|
| Glucose | Benedict's solution turns from blue to yellow-orange-red |
| Starch | Iodine solution turns from red-brown to blue-black |
| Fat/Oil | Fats and oils leave a spot on brown paper that light can pass through |
| Protein | Biuret solution turns from blue to purple or mauve |

2. Copy the table below in your notebook for recording your observations.

| | Final Colours Using Indicators | | | Light Transmittal Through Brown Paper |
|---|---|---|---|---|
| Substance Tested | Benedict's Solution | Iodine Solution | Biuret Solution | |
| Glucose | | | | |
| Corn Starch | | | | |
| Vegetable Oil | | | | |
| Gelatin | | | | |
| Unknown | | | | |

3. Label the test tubes with the names of the substances you are testing.

*Testing for Glucose*

4 Place a small amount of each substance to be tested in separate test tubes.

5 Place a small amount of water in a test tube.

6 Add 10 drops of Benedict's solution to each test tube. Heat the tubes in a hot water bath for about 2 min. Record your observations.

*Testing for Starch*

7 Place several drops of each substance to be tested and water into separate places on the spot plate.

8 Place a drop of iodine solution on each substance. Record your observations.

*Testing for Lipids*

9 Divide a piece of brown paper into five sections. Label each section with the name of the substance to be tested on it: one section for water, one for glucose, etc. Using a clean medicine dropper each time, place a drop of each substance on the appropriate spot on the brown paper.

10 Leave the paper for 5 to 10 min in a vertical position. After the time is up, look through the paper by holding it up to the light.

*Testing for Proteins*

11 Place several drops of each substance and an equal number of drops of water into separate places on a clean spot plate.

12 Add three drops of Biuret solution to each of them. Record your observations.

*Testing an Unknown Sample*

13 Use appropriate materials and equipment to test an unknown sample for the presence of glucose, starch, lipids, and proteins.

14 Wash your hands after you have completed all the tests and cleaned up your equipment. Follow your teacher's instructions for disposing of all the substances you have used.

**Analyzing and Interpreting**

15 Which substances contained each of the following molecules? In each case, how did you know?

a) glucose

b) starch

c) lipids

d) proteins

16 What organic substance or substances were in the unknown sample?

**Forming Conclusions**

17 Describe how you determined what organic substance or substances were in your unknown sample. Use your data to support your conclusions.

## Proteins and Amino Acids

Foods such as meat, fish, eggs, and dairy products add **proteins** to our diet. Proteins have many functions. They are used by organisms for growth and repair, and as a source of energy. They are the main component of **enzymes**. Recall that enzymes are catalysts that control chemical reactions in organisms.

A protein is an organic compound made up of units called **amino acids**. Figure 1.22 shows the structure of an amino acid. The way amino acids form proteins is similar to the way glucose units join together to form complex carbohydrates such as starch.

**Figure 1.21** Fish is an excellent source of protein. Sometimes it is eaten raw as sushi or sashimi. Both are Japanese dishes.

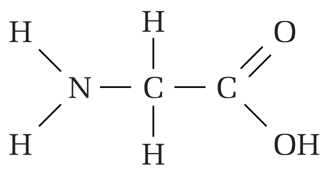



**Figure 1.22** This diagram shows the structure of the amino acid glycine. Each amino acid has a central carbon atom. Amino acids also include nitrogen, hydrogen, and oxygen atoms, along with more carbon atoms. Some also contain sulfur.

Each protein has its own number and arrangement of amino acids. In general, a protein contains between 40 and 500 amino acid units. Insulin, for example, contains 51 amino acid units arranged in two chains, as shown in Figure 1.23. Twenty different kinds of amino acids are common in protein molecules. Green plants convert glucose into amino acids.

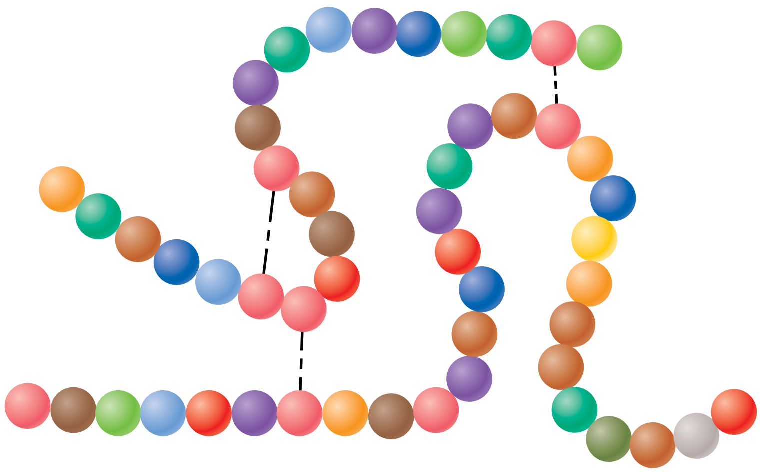


**Figure 1.23** An insulin molecule. Each circle represents an amino acid unit. Different colours represent different amino acids.

### Nucleic Acids

**Nucleic acids** are the largest and most complicated molecules found in living things. All cells contain two important nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA and RNA are made up of three substances: phosphates, a simple sugar called ribose, and nitrogen-containing molecules. Nucleic acids play a major role in heredity and in controlling a cell's activities.

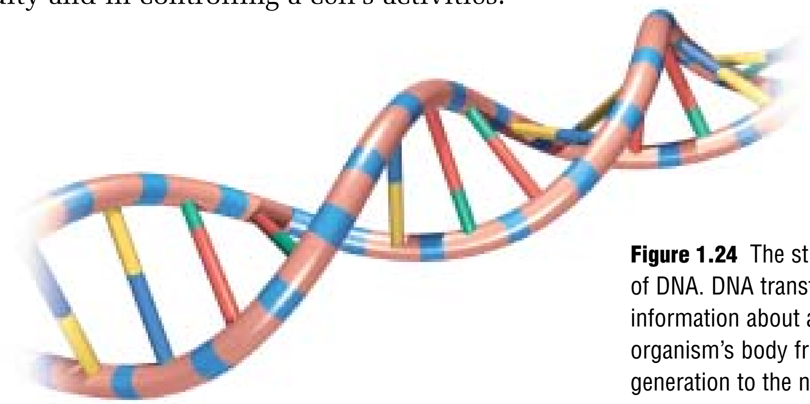


**Figure 1.24** The structure of DNA. DNA transfers information about an organism's body from one generation to the next.

**reSEARCH**

**Organic or Inorganic?**

Find out whether the following substances are organic or inorganic: gasoline, nitrogen gas, canola oil, vinyl, hydrogen sulfide, protein. For each one, write out the chemical formulas for its compounds. Describe how the substance is used. Begin your information search at www.pearsoned.ca/scienceinaction.

## Check and Reflect

### Key Concept Review

1. Define the term "organic compound." Give two examples of these compounds.
2. List four elements that are macronutrients for plants. Explain their importance in plants and in humans.
3. What is a micronutrient? Give one example.
4. What elements are found in the following compounds?
   a) carbohydrates
   b) proteins
   c) lipids
   d) nucleic acids

### Connect Your Understanding

5. Imagine that your favourite house plant is growing well but it is not flowering. A friend suggests that your plant may be lacking phosphorus. Is that a possibility? Explain your answer.
6. Explain the term "optimum amount" using one of the following as an example: potassium for plants or selenium for animals.
7. Which term in each of the following groups of four terms includes the other three?
   a) carbohydrate, glycogen, starch, glucose
   b) sugar, DNA, phosphate, nitrogen-containing base
   c) fats, waxes, oils, lipids

### Extend Your Understanding

8. Suppose you are a farmer and your crop is not growing as well as it has in the past. You notice that the lower leaves of the plants are turning yellow. Recall that chlorophyll gives leaves their green colour and is important in photosynthesis. Use the table on page 197 to help you answer the following questions.
   a) What nutrient deficiencies might be causing this problem?
   b) What would be your next step to solve the problem?
9. A sample solution was sent to a laboratory for examination. When Benedict's solution was added, and the sample was heated, a red precipitate formed. When Biuret solution was added, the sample remained blue. What substance was identified in the solution?

*info***BIT**

**Eating Elements**

In 1295, when Marco Polo was on the way to China, some of his pack animals became sick and died. The ones that did not become sick were the ones that came from the area through which they were passing. It is now thought that the local pack animals avoided those plants that had accumulated selenium from the soil. The other animals ate the selenium-rich plants and died from selenium poisoning.

# 1.4 How Organisms Take in Substances

**Figure 1.25** Inorganic chemicals from the environment are taken up by producers which then provide food for consumers.

Plants and animals rely on the environment for the substances they need to live. Plants take in inorganic compounds to make organic compounds. Consumers must rely on organic compounds made by plants for their energy, growth, and repair. Consumers obtain these compounds by either eating plants or eating other organisms that eat plants.

When organisms take in the chemicals they need, they may also be taking in other substances. Sometimes, these are harmless. For example, when you drink pop, you are taking in water, which you need, but you are also taking in the flavouring and colouring in the pop. You don't need them and they are harmless. Sometimes the other substances may be harmful. For example, a lake beside a coal-fired generating plant may contain high levels of mercury. If you ate fish caught near the plant, you would take in this harmful substance.

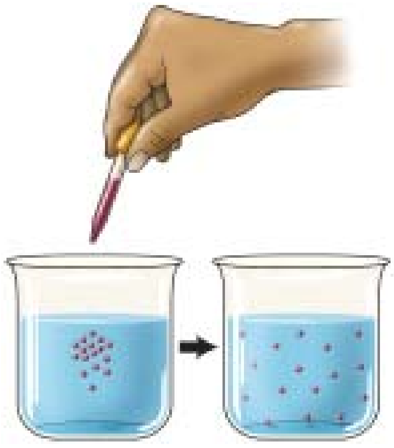


**Figure 1.26** Diffusion is a process in which substances dissolved in water move from an area of higher concentration to one of lower concentration.

## Uptake of Substances by Plants

Nutrients enter the roots of plants either passively or actively. Passive uptake does not require the plant to use any energy. It occurs through a process called **diffusion**. Diffusion is the movement of molecules from an area of higher concentration to one of lower concentration. Figure 1.26 shows diffusion occurring in a solution of food colouring and water. The food colouring gradually moves from the more concentrated area where it enters the water until it is spread evenly throughout the water.

Similarly, some nutrients move into the roots of plants by diffusion.

They move from the area of higher concentration outside the roots to the area of lower concentration within the roots. The movement continues until the concentration of nutrients is the same both inside and outside the plant roots. You can think of diffusion as an evening out or balancing of the concentration of a substance in solution. No energy is required for this process because the molecules naturally diffuse to the areas of lower concentration.

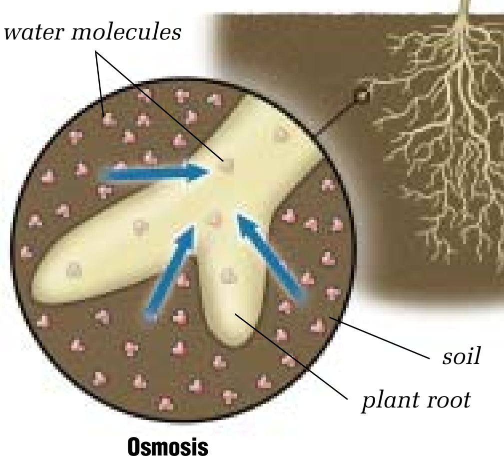
### Osmosis

Water moves into plant roots by a special type of diffusion called **osmosis**. In the process of osmosis, water moves through the walls of the plant's roots from an area where there are more water molecules to an area where there are fewer water molecules. As the plant uses water for its growth and maintenance, it draws water up from the roots. As the number of water molecules within the roots decreases, more water molecules move into the roots from the surrounding soil. Figure 1.27(a) shows this movement.

### Active Transport

Plants need high concentrations of some nutrients in their roots. The concentrations of these nutrients may be higher in the roots than in the water in the surrounding soil. To maintain these high concentrations, plants must move some nutrients from the soil, an area of lower concentration, into their roots. To move nutrients in this direction, plants use a process called **active transport**. In active transport, plants must use energy to move the molecules of nutrients in the direction opposite to diffusion. This energy is used by specific molecules in the root cells that transport the nutrient molecules into the plant roots. Figure 1.27(b) shows the movement in active transport.

**Figure 1.27(a)** Osmosis. Water moves through the walls of the plant's roots from an area where there are more water molecules to an area where there are fewer water molecules.



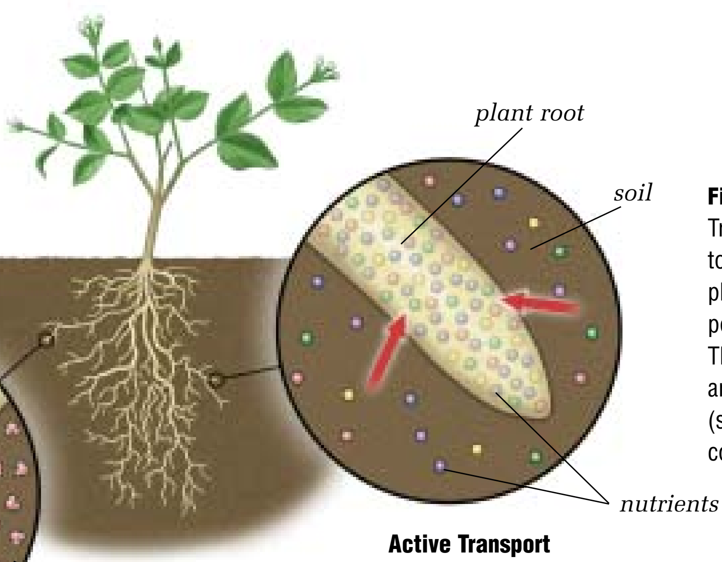




**Figure 1.27(b)** Active Transport. Plants use energy to transport nitrogen, phosphorus, sulfur, and potassium into their roots. The nutrients move from an area of lower concentration (soil) to one of higher concentration (roots).

## Ingestion and Absorption of Materials by Animals

Humans and other animals obtain the 25 elements our bodies need for normal growth and function from the air we breathe and the food we eat.

The process of taking food into our bodies is called **ingestion**. Every time you drink or eat, you are ingesting food. Most of the ingested food must be broken down into smaller particles so our bodies can absorb the nutrients from it.

Humans and other animals break down food mechanically and chemically. An example of mechanical breakdown is chewing food. Chemical breakdown occurs in the mouth, stomach, and small intestine with the help of enzymes that speed up the chemical reactions. The breakdown or digestion of large organic molecules occurs by a process called **hydrolysis**. "Hydro" refers to water and "lysis" means breakdown. A substance that is broken down by hydrolysis has been **hydrolyzed**. For example, when you eat potatoes, the large starch molecules are hydrolyzed into double sugars called maltose, and then into single sugars called glucose. This reaction can be written in the following way.

$$C_{12}H_{22}O_{11(aq)} + H_2O_{(l)} \longrightarrow 2\,C_6H_{12}O_{6(aq)}$$

$$\text{maltose} + \text{water} \longrightarrow \text{glucose}$$

Nutrients such as glucose and amino acids are absorbed through cell membranes and into the bloodstream. The blood carries them to cells throughout the body where they are either used or stored.

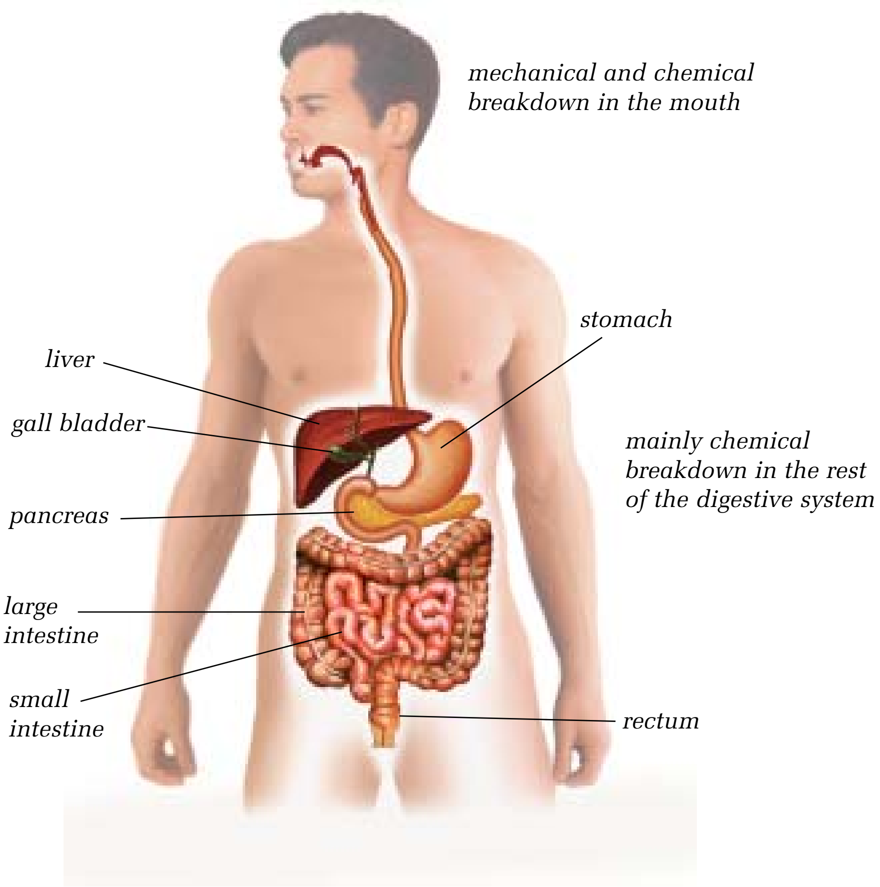



**Figure 1.28** The food you ingest is broken down mechanically and chemically in your digestive system.

Activity C-5

Inquiry

# Breakdown of Starch by Hydrolysis

### Before You Start

Large starch molecules are formed by many glucose molecules joined together. The bonds that join the glucose molecules can be broken in several ways. Two ways are:

- heating at high temperatures
- using enzymes in the digestive tract as catalysts in the hydrolysis of the starch

### The Question

Which of the following processes breaks down starch more quickly: heating or using enzymes?

### The Hypothesis

TOOLBOX

Restate the question in the form of a hypothesis.

### Procedure

1. Place 4 drops of starch suspension in a spot plate. Add 1 drop of iodine solution. Record your results.
2. Label two beakers with the numbers 1 and 2. Place 50 mL of starch suspension into each beaker.
3. Place beaker 1 on a hot plate. Boil and stir the contents for 5 min.
4. Place 4 drops from beaker 1 in the spot plate, and test for the presence of starch. Record your observations.
5. If you observe a positive starch test, repeat steps 3 and 4 two more times. Do not repeat these steps more than twice.
6. In beaker 2, add 10 mL of digestive enzyme suspension to the starch suspension, and stir for 5 s.
7. Place 4 drops from beaker 2 in the spot plate and test for the presence of starch. Record your observations.
8. Follow your teacher's instructions for disposing of all the substances you have used.

### Analyzing and Interpreting

9. What are the manipulated and responding variables in this investigation?
10. Explain why no starch was present in one of the beakers.
11. Was your hypothesis correct? Explain why or why not.

### Forming Conclusions

12. Which process broke down the starch more quickly? Support your answer with your data.

### Applying and Connecting

Corn starch is hydrolyzed to produce various kinds of corn syrup, which are used for making products such as candy and chewing gum.

### Extending

Design and carry out an experiment to show how the temperature of an enzyme suspension affects the rate of hydrolysis of starch.

***Materials & Equipment***

- corn starch suspension
- iodine solution
- digestive enzyme suspension
- hot plate
- 2 beakers
- spot plate
- stir stick
- graduated cylinder
- eye dropper

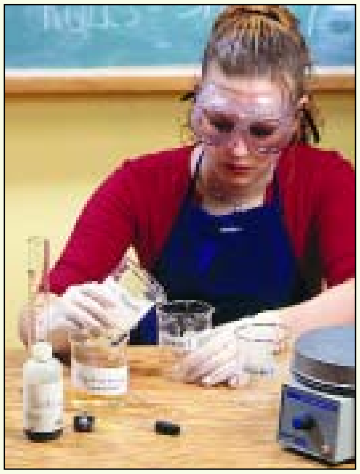


**Figure 1.29** Both beakers contain starch suspension.

**Caution!**
Hot surfaces burn. Leave beaker 1 on the hot plate to cool.

## Taking in Nutrients in Different Environments

Organisms inhabit almost all parts of Earth—from the icy Arctic to tropical jungles, and from mountain slopes to deep under the ocean. Where organisms live affects how and when they can obtain nutrients. For example, plants living in the north can obtain nutrients only during a short growing season. Plants in the desert often have methods to limit the growth of other plants around them. This reduces the competition for the limited nutrients available. Figure 1.30 shows examples of the nutrient sources for organisms in a variety of environments.

**Figure 1.30** Life in a variety of environments

**Figure 1.30(a)** Anemones are animals that live attached to rocks in the ocean. They capture food with their tentacles.

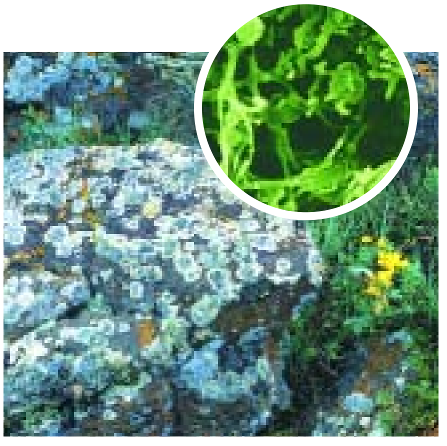


**Figure 1.30(b)** Lichens are often the first organisms to colonize an area. They have been found in cold, dry valleys in Antarctica, as well as on bare rocks high in the mountains. Lichens are made up of fungi and algae living together.

**Figure 1.30(c)** Bread mould is a fungus that secretes digestive enzymes. The enzymes help break down the bread into small molecules that can be absorbed into the fungal cells.

**Figure 1.30(d)** Desert soil does not hold water and contains little organic material. Plants and animals in deserts are adapted to going for long periods without water.

**Figure 1.30(e)** Decaying plant and animal materials enrich the soil in grasslands.

**Figure 1.30(f)** The treeless, flat areas of the north are called *tundra*. Only a few centimetres of the ground thaw in the tundra in the summer. Plants must grow and reproduce quickly when the temperature is favourable and nutrients are available.

### Substrates

A **substrate** is the material on which an organism moves or lives. Some organisms are attached to their substrate. For example, the sea anemone in Figure 1.30(a) attaches itself to rocks in intertidal zones, where the water is very turbulent. It obtains its nutrients by capturing food with its tentacles. Other organisms obtain nutrients from their substrate. For example, the bread mould shown in Figure 1.30(c) breaks down the molecules of its substrate, the bread, to obtain nutrients.

You may be surprised by the substrates on which some organisms are able to live. If you have ever hiked high in the mountains in early summer, you probably saw snow still remaining from the winter. Sometimes this snow is red and smells like watermelons. In the early 1800s, observers thought that iron from a meteorite must have been responsible for the red snow. Soon after, a biologist observed single-cell algae in the coloured snow. These algae manage to survive on a substrate that is near freezing, poor in nutrients, and often acidic. The red pigment masks the green chloroplasts that enable the algae to carry out photosynthesis.

**reSEARCH**

**Nutrients and Substrates**

Choose one of the environments shown in Figure 1.30 and find out about the organisms that live there. Describe the nutrients they obtain from their environment and how they take them in. Identify the substrates on which they live. Prepare a poster or electronic presentation to summarize your research. Begin your research at www.pearsoned.ca/scienceinaction.

## Check and Reflect

**Key Concept Review**

1. Define the following terms:
   a) diffusion
   b) osmosis
   c) active transport
2. What is the substrate for the lichen in Figure 1.30(b)?
3. What happens to food when you ingest it?
4. What effect do hydrolysis enzymes have on the rate at which large organic molecules break down?

**Connect Your Understanding**

5. Plants take in water from the soil. Why does the water move from the soil into a plant's roots?
6. a) How is the process of diffusion similar to active transport?
   b) How are the two processes different?
7. Why are the algae that live on snow able to survive high in the Rockies in early summer?

**Extend Your Understanding**

8. a) Write a hypothesis for an experiment to show the effect of temperature on the rate of diffusion.
   b) Identify the manipulated and responding variables.
   c) Write the procedure for the experiment.

## Careers and Profiles

# CHEMICAL RESEARCHER AND THEORETICAL CHEMIST

On a hot summer day in the Rocky Mountains, bark beetles were crawling all over the screen door of a trailer where chemicals were stored. Dr. Hal Wieser, Dr. William Laidlaw, and their graduate students were surprised to see the beetles, but they could guess why they were there. One of the chemicals, a pheromone, is used in traps to attract bark beetles—it must have escaped from its container inside the trailer.

**Figure 1.31(a)** A female bark beetle and her eggs in the inner bark of a lodgepole pine.

Bark beetles are small brown-black insects that burrow into the bark of mature or injured trees. Unfortunately, the beetles carry a fungus with them that causes the trees to die. One of the techniques for controlling the beetles involves trapping them, using pheromones as bait. Once trapped the insects are killed.

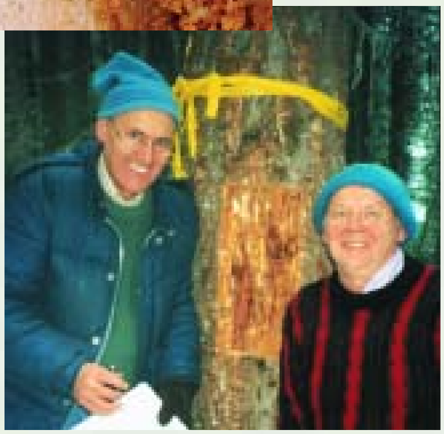


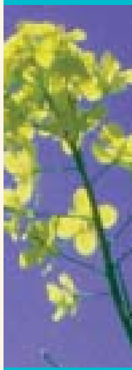
**Figure 1.31(b)** Dr. Hal Wieser (left) and Dr. William Laidlaw at work in the forest.

The beetles detect the pheromones with their antennae much the way you detect different smells with your nose. Each species of insect is attracted to different pheromones with different chemical structures. By using pheromones, foresters and forest researchers can target only those insects that must be controlled. This avoids the problem that often arises with widespread spraying of insecticides—both non-targeted and targeted species are killed.

Many people with a variety of skills work together to help protect forests from insects that can kill trees. Dr. Wieser is a research chemist working at the University of Calgary. He became interested in pheromones when he was trying to establish a link between the sense of smell and the shapes of molecules. Dr. Laidlaw is a theoretical chemist interested in the computer modelling of beetle behaviour. For their experiments, they often work with people who know about the biology of the beetle and people who know about forests and timber resources.

1. Why do you think scientists often work together?
2. Think about projects on which you've worked with other students. What advice would you give on how to work well with others on projects?

## SECTION REVIEW



## Assess Your Learning

### Key Concept Review

1. Define the term "macronutrient" and give three examples.
2. List two roles of potassium in plants and two roles in humans.
3. Identify two elements that are known to enhance plant growth but that limit growth if too little or too much is available.
4. What is a sanitary landfill site?

### Connect Your Understanding

5. Use an example to help explain what a neutralization reaction is.
6. Explain the difference between organic and inorganic compounds. Give one example of each.
7. Match the organic molecules with the elements that compose them.

| | |
|---|---|
| carbohydrates | C, H, N, O |
| proteins | C, H, O |
| nucleic acids | C, H, O, N, P |

8. a) What do the numbers 10-0-0 on a fertilizer label mean?
   b) What type of growth does this fertilizer promote?
9. a) Why do farmers use pesticides?
   b) Why do some people want farmers to use lower amounts of pesticides?

### Extend Your Understanding

10. What types of organic molecules make up a hamburger? In your answer, name the part of the hamburger that includes each type of compound. Include the bun, the meat patty, and everything on the burger.
11. What could you do at home to help minimize the environmental damage caused by pollution from gas and oil processing?

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

In this section, you looked at chemicals in the environment that support or harm organisms. Science can play a role in helping people understand the impact of the human use of chemicals on the natural world. Technology can help reduce or control this impact. Consider the following questions, and use examples from this section to support your answers.

1. Identify three examples of human impact on the chemical composition of the environment. For each example, explain how science can help us understand these impacts.
2. Describe an example of how science and technology can be used to reduce the impact that humans have on ecosystems.

# 2.0 The quantity of chemicals in the environment can be monitored.

## Key Concepts

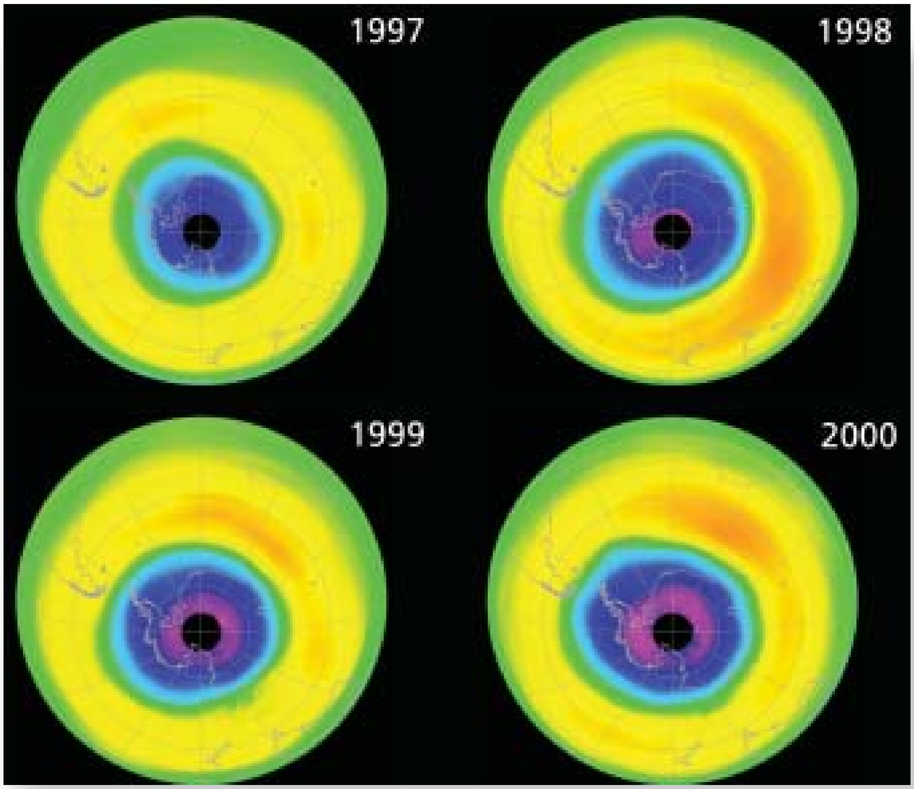
In this section you will learn about the following key concepts:

- air and water quality
- concentration and dispersal
- uncertainties in environmental monitoring and in assessing toxicity and risk

## Learning Outcomes

When you have completed this section, you will be able to:

- describe and illustrate the use of biological monitoring as a method of determining environmental quality
- identify chemical factors in the environment that might affect the health and distribution of living things
- apply and interpret measures of chemical concentration in parts per million, billion, or trillion




The hole in the **ozone layer** over the Antarctic concerns many scientists. Ozone ($O_{3(g)}$) forms a layer that shields Earth from much of the damaging ultraviolet (UV) radiation from the Sun. Some UV radiation passes through this shield normally, but now more is getting through. Experts predict more skin damage and cancers in humans, as well as effects on other organisms. The ozone layer is 15 to 50 km above Earth's surface, but ozone also exists at ground level. This ground-level ozone can cause health problems.

The photo of the hole in the ozone shown here was taken from a satellite. Photos such as these are important in **monitoring** the ozone layer. Monitoring means keeping track of something for a specific purpose. At ground level, scientists use sampling and other techniques to monitor the ozone levels in the air. In this section, you will learn about the different chemicals that must be monitored so we can protect water and air quality. You will also learn about chemicals monitored in the atmosphere to protect life on Earth.

# 2.1 Monitoring Water Quality

**Figure 2.1** Would you swim in this water?

If you wanted to jump into a lake for a swim, you probably would not choose a lake like the one in Figure 2.1. And you would not be the only one put off by the lake's appearance. Studies show that when lake transparency decreases, property values of cottages and homes around the lake decrease as well.

Lakes may become cloudy in summer because of excessive algal growth. This reduces the oxygen content in the lake, which affects the types of organisms that can live there. Insects and fish that live in water like this are different from the ones that live in a clear lake. Trout, for example, are one of the first fish to die when the concentration of dissolved oxygen decreases.

Clarity is not a good indicator of water quality. Clear water can sometimes be harmful to humans and other organisms. For example, lakes affected by acid rain are crystal clear and lifeless.

Water quality is determined according to what the water is used for. Both provincial and federal governments set guidelines for water quality in five categories of water use:

- human drinking water
- recreation such as swimming
- livestock drinking water
- irrigation
- protection of aquatic life

The guidelines are designed to protect humans, animals, crops, and other organisms that live in or near water systems. Scientists and technicians make sure that these guidelines are being met by monitoring water quality, using both biological and chemical indicators.

*info***BIT**

**Safe and Unsafe**

The insecticide pyrethrum is produced from plants such as chrysanthemums. It is used to eliminate pests such as aphids. Pyrethrum is safe for mammals, including humans. However, it is very poisonous to fish and other aquatic life, so it should not be used near ponds or other bodies of water.

## Biological Indicators

Scientists use organisms that live in water to help determine water quality. These indicator organisms include fish, plants, worms, insects, plankton (microscopic algae and tiny animals), protozoa, bacteria, and viruses.

### Microbiological Indicators

Microscopic organisms such as bacteria can cause serious health problems if they are present in large enough numbers. Small samples of water are taken frequently from water sources that people use. These samples are processed to determine the numbers and types of microscopic organisms, such as harmful bacteria (e.g., some strains of *Escherichia coli*). If the count is too high, additional water treatment may be necessary.

### Aquatic Invertebrates

Water with a large number of harmful bacteria can cause illness. Other biological indicators of water quality do not cause illness themselves but can show the effects of pollution, which may indicate unsafe water. Aquatic invertebrates are one group of indicator organisms. **Invertebrates** are animals without backbones. Those that live in water include insects, crustaceans (such as shrimp), worms, and mollusks (such as clams). They are used for monitoring because different invertebrates prefer different living conditions. For example, the organisms living in a stagnant pond are different from those living in a pond with a higher concentration of dissolved oxygen. Water temperature and pH can also affect the types of organisms found in an area.

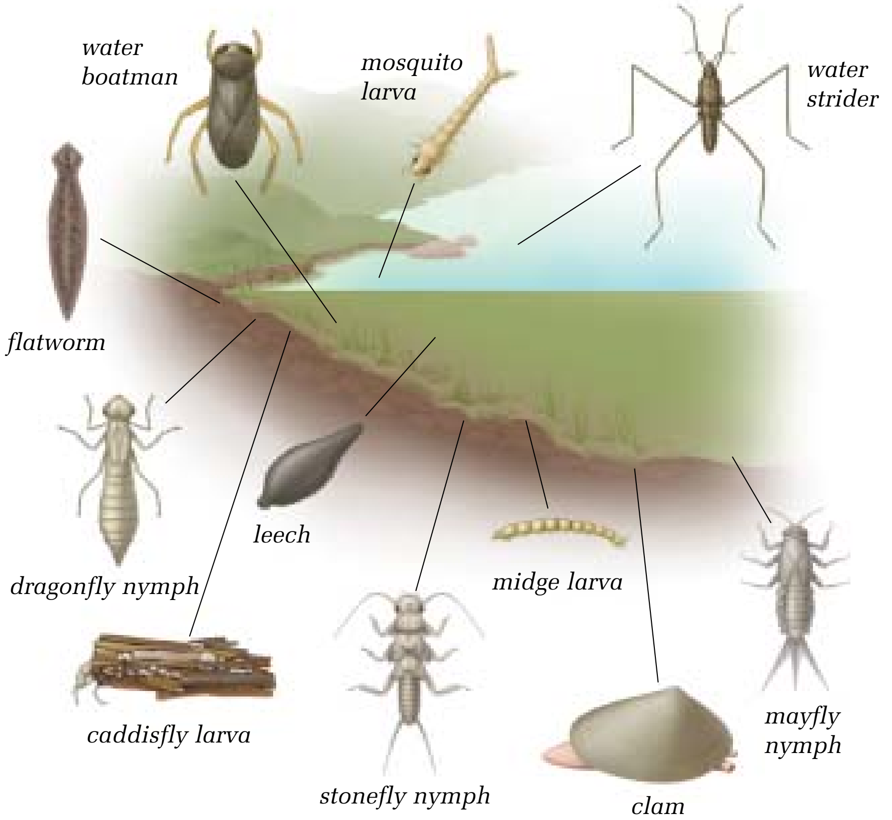



**Figure 2.2** Examples of the many different kinds of aquatic invertebrates

**QUICKLAB**

## Identifying Aquatic Invertebrates

**Purpose**

To identify aquatic invertebrates used in biological monitoring of water quality. You will apply your knowledge of invertebrates later in this unit to help assess water quality.

**Procedure**

1. Place the invertebrate with some water in a clear container such as a Petri dish, watch glass, or microscope slide.
2. Using a magnifying glass or dissecting microscope, observe the organism's features such as legs/no legs, gills/no gills on abdomen, wings/no wings. Use Figure 2.2 to help you identify the invertebrates in your sample. Record your identification. If you are unable to identify the organism, draw a diagram of it. Record as many different organisms as you can.
3. Wash your hands with soap when you are finished.

**Questions**

4. How many different types of invertebrates were you able to identify?
5. Work with the rest of the class to identify those organisms that you and other students were not able to identify.

***Materials & Equipment***

- water sample from pond or stream containing invertebrates
- magnifying glass or dissecting microscope
- medicine droppers
- spoon
- watch glass, Petri dish, or microscope slide

## Aquatic Environments

If the pH of the water in an aquatic environment is below 5.0, you will not find many fish there, especially young ones. Some insects such as mayflies are also very sensitive to acidic environments and environments that have little dissolved oxygen. The diversity of all organisms decreases as acidity increases and dissolved oxygen decreases. For example, few insects and many worms may mean that the water contains little dissolved oxygen. Recall from earlier studies that diversity refers to the number of different species in an ecosystem.

A pond that supports a wide variety of organisms probably has good water quality for allowing organisms to survive. However, it cannot be considered safe for humans to drink until it is tested to make sure.

## Chemical Factors That Affect Organisms

Pure water is made up of only $H_2O_{(l)}$ molecules, but water in the environment is never completely pure. It can contain many different organic and inorganic compounds. The concentration of these compounds affects water quality. The following are most commonly monitored as indicators of water quality:

- dissolved oxygen
- acidity
- heavy metals
- plant nutrients such as nitrogen and phosphorus
- pesticides
- salts such as sodium chloride and magnesium sulfate

## Measuring Chemicals in the Environment

The concentration of chemicals in the environment is usually measured in **parts per million** (ppm) or milligrams per litre (mg/L). For example, the human nose can detect chlorine in water at a concentration of 1 ppm of chlorine. That means that there is 1 part chlorine for every 1 million parts of the chlorine/water solution. One part per million means that one unit of an element or chemical can be found in one million units of solution.

Here is an example to help you better understand parts per million as a unit of measurement. Suppose you put 999 mL of water in a large beaker or bucket, add 1 mL of food colouring, and stir to make a solution. The concentration of food colouring in the container is 1 mL of food colouring per 1000 mL of solution, or you can say, 1 part food colouring per 1000 parts solution.

**Figure 2.3** The beaker above has 1 part food colouring for every 100 parts of solution. The other beaker below has 100 ppm.

Now you will make a very dilute solution using the solution you just made. Pour 999 mL of water into another large container. Add 1 mL of the mixture from the first container. This contains 0.001 mL of food colouring. Stir. The concentration in the second container is therefore 0.001 mL of food colouring per 1000 mL of solution, or 0.001 parts food colouring per 1000 parts solution. To express this as parts per million, write:

$$0.001 \text{ parts per } 1000 \text{ parts} = x \text{ parts per } 1\,000\,000 \text{ parts}$$

where $x$ is the number of parts per million parts of solution.

Write this statement as a ratio.

$$0.001 : 1000 = x : 1\,000\,000$$

Write each ratio as a fraction.

$$\frac{0.001}{1000} = \frac{x}{1\,000\,000}$$

Multiply each side of this equation by 1 000 000 to clear the fractions.

$$\frac{0.001}{1000} \times 1\,000\,000 = \frac{x}{1\,000\,000} \times 1\,000\,000$$

$$1 = x$$

The concentration of food colouring in the diluted solution in the second container is now 1 part per million parts solution, or 1 ppm.

Sometimes you may encounter even lower concentrations of chemicals in parts per billion (ppb) and parts per trillion (ppt). Here's an example to show the difference between these measurements:

- 1 drop of food colouring in a half-full bathtub is about 1 ppm
- 1 drop of food colouring in a full swimming pool is about 1 ppb
- 1 drop of food colouring in the amount of water needed to fill 1000 swimming pools is about 1 ppt

Measuring parts per trillion of anything is difficult and requires special, costly equipment. Only extremely hazardous substances are measured to this level of concentration. For example, the average concentration of polychlorinated biphenyls (PCBs) in the Great Lakes has been measured at 4 ppt. These manufactured oils are used in electrical equipment. They persist in the environment and accumulate in the body tissues of animals.

## *SKILL* PRACTICE

### PARTS PER MILLION

Try these examples for practice using parts per million as a unit of measure.

Suppose you make a food colouring solution by putting 99 mL of water in a beaker and adding 1 mL of food colouring. The concentration of food colouring in this beaker is 1 part food colouring per 100 parts solution.

• Calculate this concentration in parts per million.

You then add 1 mL of this solution to 99 mL of water in a second beaker. This creates a concentration of 0.01 parts of food colouring per 100 parts of solution.

• Calculate this concentration in parts per million.

Now suppose you take 1 mL of the solution in the second beaker and add it to 99 mL of water in a third beaker.

• What is the concentration of food colouring in this solution in parts per million?

## DISSOLVED OXYGEN

Imagine white-water rafting down a roaring river. As the water churns over and around rocks, oxygen from the air is dissolving into it. Dissolved oxygen is essential for the health of aquatic life such as fish, insects, and micro-organisms. The level of dissolved oxygen in water depends on:

- temperature
- turbulence due to wind or the speed of moving water
- the amount of photosynthesis by plants and algae in the water
- the number of organisms using up the oxygen

Five milligrams per litre (equal to 5 ppm) of dissolved oxygen will support most organisms that live in lakes and streams. The following table gives examples of levels of dissolved oxygen needed by aquatic invertebrates.

| Dissolved oxygen (ppm or mg/L) | Invertebrates |
|---|---|
| 8 | Large numbers of diverse invertebrates |
| 6 | Mayflies, stoneflies, and beetles begin to disappear |
| 4 | Freshwater shrimp, midge larvae, and worms can survive |
| 2 | Midge larvae and some worms can survive |

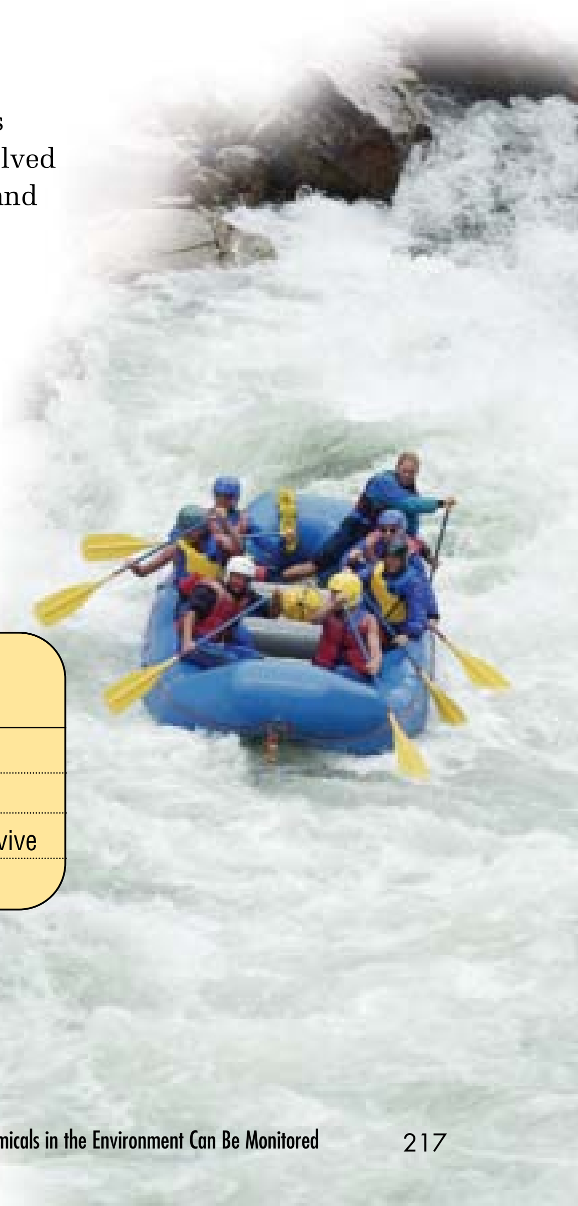


**Figure 2.4** Rapids expose more water surface to the air than smooth river flow does. The turbulence allows more oxygen from the air to dissolve in the water.

ACTIVITY C-6

**Inquiry**

# HOW DOES OXYGEN GET INTO THE WATER?

## Before You Start

In this activity, you will use an indicator to determine the amount of dissolved oxygen in a water sample. The indicator changes colour according to the amount of oxygen present.

### *Materials & Equipment*

- 100 mL boiled, then cooled water
- dissolved oxygen measuring kit
- 2 small beakers
- small jar with tight-fitting lid (e.g., baby food jar)

**Figure 2.5** Step 2

## The Question

What is the effect of turbulence on the amount of dissolved oxygen in water?

## The Hypothesis

TOOLBOX

Reword the question in the form of a hypothesis.

## Procedure

1. Pour 50 mL of the boiled, cooled water into a small beaker.
2. Following the directions on the dissolved oxygen kit, measure the amount of dissolved oxygen in your sample in milligrams per litre. Record your measurement.
3. Pour the remaining 50 mL of the boiled, cooled water into a jar with a tight-fitting lid. (The jar should be big enough so that a large amount of air remains after the water sample is placed in it.)
4. Shake the jar vigorously for 1 min.
5. Open and close the jar and repeat step 4 two more times.
6. Following the directions on the dissolved oxygen kit, measure the amount of dissolved oxygen in the shaken sample in milligrams per litre. Record your measurement.

## Analyzing and Interpreting

7. Why did you have to use water that had been boiled and then cooled for this activity?
8. Would the amount of dissolved oxygen in the shaken water sample change if the water was boiled and then cooled again? Explain your answer.
9. What was the manipulated variable in this experiment? What was the responding variable?

## Forming Conclusions

10. Use your observations to explain the effect of turbulence on the amount of dissolved oxygen in the water.

## Applying and Connecting

The bubbles you see breaking the surface in an aquarium are produced by a device called an aerator. An aerator bubbles air through the water in the aquarium to replace the dissolved oxygen that has been used up by fish and other organisms.

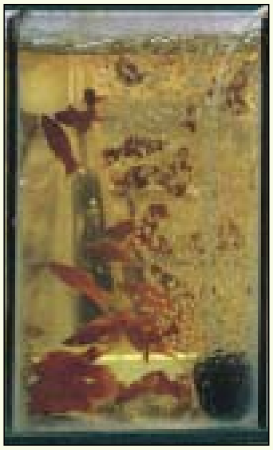


**Figure 2.6** An aerator in an aquarium

## Extending

Design an experiment that shows the effect of temperature on the concentration of dissolved oxygen in water.

## Phosphorus and Nitrogen Content

Most aquatic organisms are sensitive to changes in the amount of dissolved oxygen in the water in which they live. One factor that can affect dissolved oxygen is an increase in phosphorus and nitrogen in the water. Phosphorus and nitrogen are important to all living things, but too high a concentration in water can cause problems.

Large amounts of phosphorus and nitrogen can enter water systems in different ways. Sewage outfalls and runoff from fertilized fields are two possible sources. Higher concentrations of these nutrients in water cause increased growth of algae and green plants. As more algae and plants grow, more die. This dead organic matter becomes food for bacteria that decompose it. With more food available, the bacteria increase in number and use up the dissolved oxygen in the water. When the dissolved oxygen content decreases, many fish and aquatic insects cannot survive. Figure 2.7 shows the effects of increased amounts of phosphorus and nitrogen on a lake.

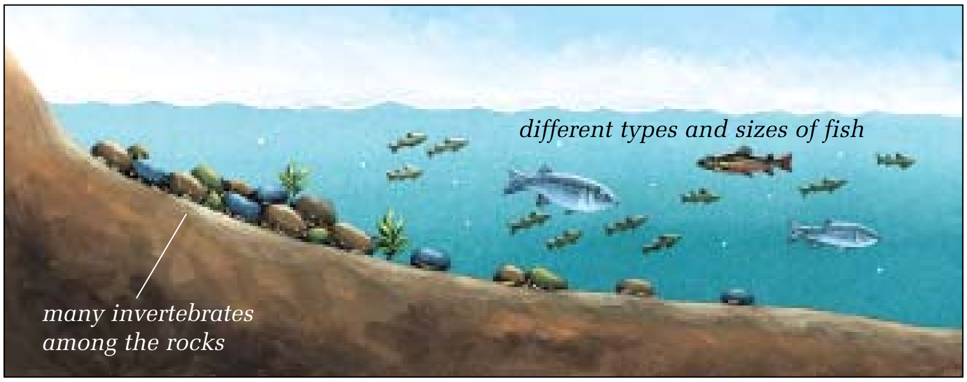



**Figure 2.7(a)** A "clean" lake contains a wide variety of organisms. These include fish and invertebrates such as mayfly nymphs, stonefly nymphs, midge larvae, and worms. The white dots represent the numbers of bacteria.

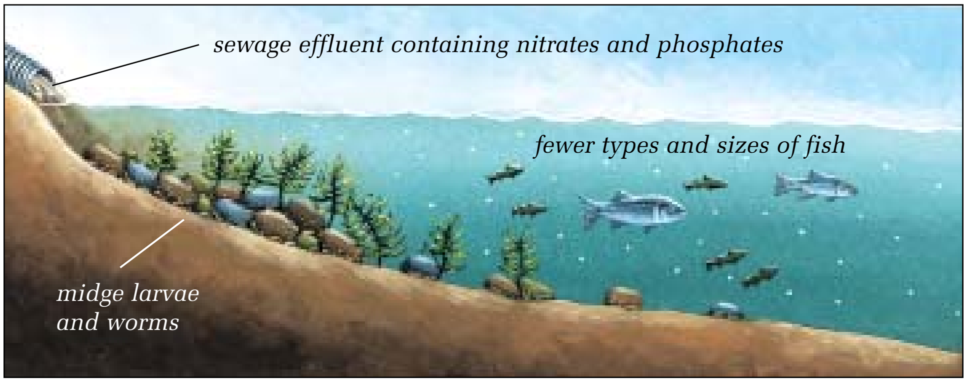



**Figure 2.7(b)** Added plant nutrients from treated sewage or runoff from fields causes increased growth of algae and plants. Fewer fish and invertebrates can live in these conditions.


**Figure 2.7(c)** Some plants die. Bacteria help to decompose them. With more food available, the population of bacteria increases. They need oxygen to survive, so they use up much of the dissolved oxygen in the water. The lake is no longer a place where fish and many insects can live.

**QUICKLAB**

## Phosphorus and "Foggy" Water

Phosphorus commonly combines with oxygen to form compounds called phosphates. These compounds in fertilizers and sewage can pollute water systems. Magnesium sulfate dissolves in water and reacts with phosphates to form magnesium phosphate. This process occurs best in a solution that is basic. Magnesium phosphate does not dissolve in water so it forms a precipitate, causing the water to appear cloudy. You can use magnesium sulfate to test water samples for the presence of phosphorus.

### Purpose

To detect phosphorus in water

### Procedure

1. Place 15 mL of each water sample in a different test tube. Add 20–30 drops of dilute ammonium hydroxide to each water sample to make the solution basic.
2. Carefully add 2 mL of magnesium sulfate solution to each sample. Let the test tubes stand for 2 to 3 min. Record your observations.
3. Follow your teacher's instructions for disposing of chemicals.

### Questions

4. In which samples did you detect phosphorus?
5. Where do you think the phosphorus came from in these samples?

### *Materials & Equipment*

- water samples (e.g., tap water, water from a local pond, water containing fertilizer, water containing a phosphate detergent)
- test tubes
- dilute ammonium hydroxide solution
- magnesium sulfate solution
- medicine dropper
- small graduated cylinder

**Caution!**
Ammonium hydroxide can burn your skin and eyes. Make sure the room is well ventilated when you work with ammonia compounds.

## Acidity

Earlier in this unit, you learned that normal rain and snow have a pH of 5.6 because carbon dioxide from the air dissolved in them to form weak carbonic acid. Precipitation with a pH lower than 5.6 is considered acid rain or snow. When this acid precipitation falls on water systems, it affects the acidity of the water. As the acidity increases, the diversity of plants and animals that live in this water decreases. Most fish disappear if the water's pH falls to 4.5.

Acidic deposition is a major problem wherever the soil and water lack natural bases to neutralize acidic precipitation. The Canadian Shield in northern and eastern Canada is an example of an affected area. The thin soils and the chemical composition of the rocks there are not able to neutralize the acid. As a result, forests and lakes have been damaged.

In areas where acid precipitation is a problem, acidic deposits build up in ice and snow in the winter. In spring, when the ice and snow melt, the acid meltwater flows into aquatic systems. This quickly creates a concentration of acid that can dramatically lower the pH of the water in a pond, slough, lake, or river for a short period of time. This is known as **spring acid shock**. It can seriously affect the eggs of aquatic organisms, as well as the young offspring of spring-spawning fish.

## Pesticides

Figure 2.8 Ladybugs can be used to control aphids because they eat large quantities of them. Spraying plants with insecticide to kill aphids may also kill ladybugs.

In section 1.0, you learned about the importance of pesticides, and some of the risks connected with their use.

Some pesticides have had longer-term harmful effects because they remained in the environment after they were no longer needed. Today most pesticides are designed to last only one growing season. They are broken down by bacteria so that they are no longer toxic.

However, even these shorter-lasting pesticides may cause pesticide-resistant pests to develop. For example, insects reproduce rapidly, so many generations can be exposed to an insecticide in one season. Some of these insects may be resistant to the insecticide. If they survive and reproduce, the whole population could become insecticide-resistant. When this happens, new insecticides must be developed, which introduces other chemicals into the environment.

In some cases, shorter-lasting pesticides may not disappear entirely from the environment. Although they break down in soil and water, they remain in the tissues of some organisms.

The large numbers of pesticides being used today are also creating another problem. Scientists are finding that water samples may contain very low concentrations of many different pesticides. One pesticide at a very low concentration might not be harmful. However, several pesticides together might mix to form a much more **toxic** or poisonous substance. Scientists are researching ways to predict the toxicity of combinations of substances in bodies of water. **Toxicity** describes how poisonous a substance is.

## Measuring Toxicity

**Toxins** or poisons are substances that produce serious health problems or death when introduced into an organism. In order to compare toxins, scientists use a measurement called **LD50**. "LD" stands for "lethal dose" and the "50" represents 50%. LD50 is the amount of a substance that causes 50% of a group of test animals to die if they are given a specified dose of the substance all at once.

| Substance | LD50 | Subject/ How delivered |
|---|---|---|
| Table salt | 3000 mg/kg | Rat, by mouth |
| Caffeine | 192 mg/kg | Rat, by mouth |
| DDT (pesticide) | 87 mg/kg | Rat, by mouth |

Different types of chemicals can affect organisms in different ways. For example, one chemical may damage the liver; another may cause brain damage. It is difficult to compare the toxicity of different chemicals if you consider these effects only. However, all toxic chemicals will cause death in some organisms if given in large enough doses. LD50 testing allows scientists to compare toxicity because they are comparing the dosage that will produce the same outcome: death.

LD50 testing is usually done on rats and mice. It is stated as the amount of chemical given per unit of body mass. It also specifies how the animal received it—the usual ways are by mouth or applied to the skin. The table in the margin shows some examples of LD50 measurements. Notice that the more toxic the substance is, the lower its LD50 number is.

## *re*SEARCH

### Heavy Metal Contamination

Choose one of the heavy metals mentioned in the text and research answers for the following questions:

- Where is the metal found?
- How could you be exposed to the metal?
- How can the metal enter your body?
- How can the metal affect your health?
- What level of exposure to the metal can cause health problems?

Begin your search at www.pearsoned.ca/scienceinaction. Prepare a summary of your research.

## Heavy Metals

In the 1950s, many people in Minimata, Japan, were becoming sick and dying from a mysterious disease that affected their nervous systems. Investigators found that the disease could be linked to eating local fish that contained large quantities of mercury. The mercury was traced to a chemical company that had been dumping its waste into the ocean. People who caught and ate the fish from this area were affected by mercury poisoning. The symptoms of mercury poisoning include numbness of arms and legs, involuntary movements, nerve damage, and brain damage.

Mercury belongs to a group of substances called **heavy metals**. They are called heavy metals because they have a density of 5 g/cm$^3$ or more. This means they are five or more times heavier than an equal volume of water. Examples include copper, lead, zinc, mercury, cadmium, and nickel.

These metals occur naturally in rocks, soil, and sometimes in water. They are mined for processing into a wide range of products. Everyday items containing heavy metals include batteries, rubber tires, gasoline, paints, pipes, thermometers, and some fertilizers.

Heavy metals can be toxic to a wide range of organisms, including humans, so water quality monitoring includes checking concentrations of heavy metals.

Usually, large amounts of heavy metals are not readily available in the environment for uptake by plants or ingestion by animals. However some situations can increase their availability. For example, acidic water can dissolve lead in pipes. Cadmium is present in some fertilizers as an impurity. Plants growing in basic soils are able to take in this cadmium. If animals eat plants containing high levels of heavy metals over long periods, they may experience serious health problems.

The heavy metal lead is especially harmful to children. It can affect normal development and cause permanent brain damage or even death. In the past, lead was used in common products such as gasoline and pipes for water systems. It is no longer used in products that might result in its

**Figure 2.9** This man has Minimata disease, a type of mercury poisoning that is named after the area in Japan where it was identified.

ACTIVITY C-7

*Experiment* **on your own**

# WHAT KILLED THE FISH?

### Before You Start

Officials are trying to determine what is causing a catastrophic fish kill along the southeast shore of Rowan Lake. Hundreds of dead fish have been reported where the Bearberry River flows into the lake. The Bearberry River is the best white-water trout stream in the province. Damage to this river will deplete the food supply for many people and harm the local tourist industry.

Biological testing has been completed, and chemical testing is underway at four sites. The results of the biological testing are shown in the following table:

| Invertebrate | Number of Organisms in a Sample | | | |
|---|---|---|---|---|
| | Site 1 | Site 2 | Site 3 | Site 4 |
| Mayfly nymphs | 187 | 0 | 35 | 233 |
| Stonefly nymphs | 155 | 0 | 23 | 162 |
| Caddisfly larvae | 34 | 0 | 6 | 27 |
| Midge larvae | 110 | 159 | 133 | 97 |
| Worms | 15 | 142 | 58 | 23 |

Your task is to determine the water quality at the four testing sites by carrying out chemical tests for dissolved oxygen, pH, and phosphates. Your teacher will provide the water samples. You will use these test results, combined with the information from the biological monitoring, to determine which site has the poorest water quality.

You may wish to review the table at the bottom of page 217. It summarizes the effect of changes in dissolved oxygen concentration on invertebrates.

### The Question

Which test site has the poorest water quality?

### Design and Conduct Your Experiment

1 From the biological data, form a hypothesis about which site will have the poorest water quality. Record your hypothesis.

2 With your partner or group, plan your procedure. Ask yourselves questions such as:
  - a) How will we test for dissolved oxygen? For pH? For phosphates?
  - b) What type of chart will we need to record data in?
  - c) How long do we have to complete the experiment?
  - d) How will we decide which site has the poorest water quality?

3 Write up your procedure. Show it to your teacher before continuing.

4 Carry out your experiment.

5 Compare your results with your hypothesis. Was your hypothesis correct? Why or why not?

6 Share and compare your experimental plan and findings with your classmates. How do your results compare with theirs? If they are different, give a possible explantation.

**Figure 2.10** Determining water quality

## Check and Reflect

### Key Concept Review

1. Governments set water quality guidelines for five categories of water use. What are these?
2. List four different groups of invertebrates that can be found in freshwater systems.
3. Identify five chemicals that are regularly monitored in aquatic systems
4. What effect does spring acid shock have on aquatic organisms?
5. Identify an invertebrate family that would probably be among the first to die if the pH of its habitat decreased.

### Connect Your Understanding

6. A student put 0.03 mL of food colouring into water to make 1000 mL of solution. Calculate the concentration of food colouring in parts per million.
7. Calculate the concentration in ppm of an alcohol/water solution if 30 drops of alcohol are stirred into water to make 1 L of solution. Note: 1 drop = 0.05 mL
8. Copy the table below into your notebook. Calculate the concentration of each solution in parts per million and fill in the last column.

| Solute (mL) | Volume of final solution (mL) | Concentration (ppm) |
|---|---|---|
| 2.0 | 1000 | |
| 0.0009 | 100 | |
| 0.62 | 10 000 | |

9. Look at the table below. In which location (A or B) will the water support the greatest diversity of organisms? Explain your answer. (The table on page 217 can help you with your answer.)

| Characteristic | Sample A | Sample B |
|---|---|---|
| Dissolved oxygen | 3.5 | 6.0 |
| pH | 5.5 | 6.5 |
| Phosphorus | high | low |

10. Explain the following statement about table salt: *The LD50 is 3000 mg/kg for rats.*

### Extend Your Understanding

11. Explain what happens when a high concentration of phosphorus enters a water system.
12. Suppose that high levels of mercury were found in your community. List at least three recommendations that you would make to the government to deal with this issue.

# 2.2 Monitoring Air Quality

Take a deep breath. The air you take in is mainly nitrogen (78%) and oxygen (21%), with some argon (less than 1%), carbon dioxide (0.03%), and traces of hydrogen and neon. If you took a deep breath in the city shown in Figure 2.11, you might find that the air irritates your throat. You might also notice that your eyes sting a bit. These are indications of poor air quality. Like water quality, air quality is determined by the number of potentially harmful chemicals.

Air quality can be determined in two ways:

- by measuring the levels of pollutants in the air
- by estimating the amount of emissions from pollution sources

Measuring the amounts of chemicals in the air is more accurate than only estimating emissions from pollution sources, such as industrial plants. Measurements of chemicals in the air include chemicals produced by natural sources such as forest fires. This provides a more complete picture of air quality. Monitoring chemicals in the air over a period of many years provides information about seasonal variations, as well as long-term trends.

**Figure 2.11** Smog seen over a city is a familiar sight on sunny days.

## Sulfur Dioxide

**Sulfur dioxide** ($SO_{2(g)}$) is a major air pollutant that forms both smog and acid rain. It can affect your respiratory system (throat and lungs) and irritate your eyes.

Sulfur dioxide and other oxides of sulfur form when oxygen combines with sulfur. The major source of sulfur dioxide is industrial processes. In Alberta, the major source of sulfur dioxide is the oil and gas industry. Sulfur dioxide and other oxides of sulfur are also formed by burning fuels such as coal, oil, and natural gas.

Industrial and electrical generating plants use devices called "scrubbers" to reduce sulfur dioxide emissions by up to 99%. Scrubbers use limestone (calcium carbonate) to convert the pollutant sulfur dioxide to a useful product. The sulfur dioxide reacts with the calcium carbonate in the scrubber to produce gypsum (calcium sulfate). The gypsum is recovered and can be used in manufacturing. Here is the equation for the sulfur dioxide and limestone reaction:

$$2\ SO_{2(g)} + 4\ H_2O_{(l)} + 2\ CaCO_{3(s)} + O_{2(g)} \rightarrow 2\ CaSO_4{\cdot}2\ H_2O_{(s)} + 2\ CO_{2(g)}$$

sulfur dioxide + water + limestone + oxygen → gypsum + carbon dioxide

### *info*BIT

**Indoor Air Pollution**

You can't always avoid air pollution simply by staying indoors. For example, a smoke-filled party room can be a health hazard. Other substances that contribute to indoor air pollution include paints, glues, and cleaning supplies.

## Nitrogen Oxides

**Nitrogen oxides** ($NOx_{(g)}$) are also major air pollutants that form both smog and acid rain. They affect the respiratory system and eyes. The "x" in the chemical formula $NO_{x(g)}$ indicates that nitrogen oxides are mixtures of $NO_{(g)}$ and $NO_{2(g)}$ and sometimes other oxides of nitrogen.

Nitrogen oxides ($NO_{x(g)}$) form mainly from combustion in vehicles. They also form by combustion in generating plants and some industrial processes, such as oil refining. The nitrogen formed by burning fuels first combines with oxygen to form nitrogen monoxide gas ($NO_{(g)}$). This then combines with oxygen in the atmosphere to form nitrogen dioxide ($NO_{2(g)}$), a brownish gas. This is the gas that gives smog its distinctive colour.

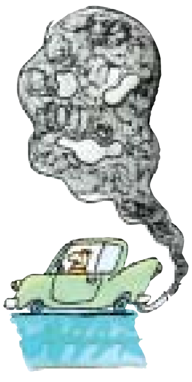
Both sulfur dioxide and nitrogen oxides are carefully monitored, especially in cities and areas where industrial processes may release these pollutants. In cities, the main concern is with pollution from vehicles.

### *SKILL* PRACTICE

#### Measuring Nitrogen Oxides

Measurements of Alberta's emissions of nitrogen oxides ($NO_{x(g)}$) are shown in the graph in Figure 2.12. Study the graph and answer the questions. Notice that the top line represents total emissions. The amounts contributed by major activities are shown in different shadings.

- What trends in nitrogen oxide emissions do the following lines on the graph show over time?
  a) total amount (top line)
  b) transportation
  c) electric power generation
  d) industrial processes
- What would you expect the total nitrogen oxide emissions to have been in the year 2000?
- Which sector contributed most to the increase in nitrogen oxides in Alberta since 1990? Suggest a reason for this increase.



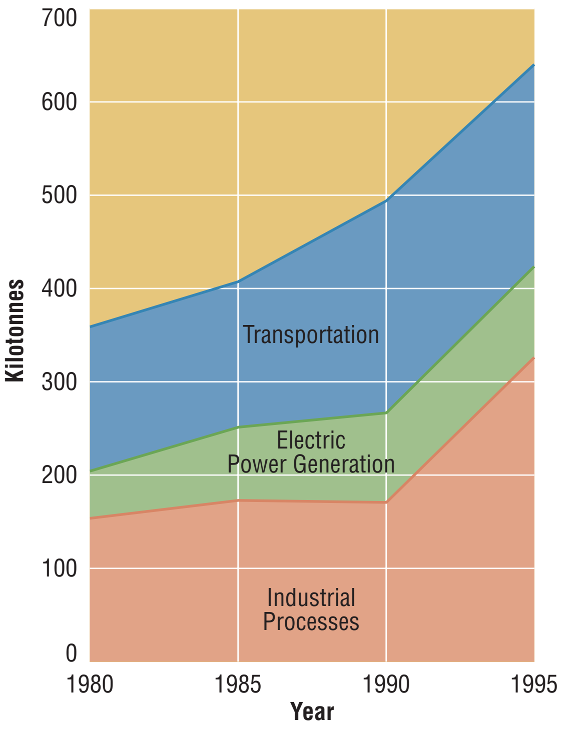



**Figure 2.12** Alberta $NO_{x(g)}$ emissions by sector 1980–1995. (Information for graph supplied by Alberta Environment)

## Carbon Monoxide

**Carbon monoxide** is called the silent killer because it is a colourless and odourless gas. When chemicals containing carbon burn, they produce carbon dioxide or carbon monoxide. Carbon monoxide ($CO_{(g)}$) forms if there is not enough oxygen to produce carbon dioxide ($CO_{2(g)}$). If there is enough oxygen during combustion, carbon dioxide is produced.

The main source of carbon monoxide from human activities is motor vehicles. Other sources are combustion of wood (e.g., fireplaces, wood stoves) and natural gas, industrial processes, airplanes, and even cigarette smoking. Carbon monoxide can also be produced in large quantities by forest fires. In cities, carbon monoxide is a major pollutant because of cars. In smaller communities, it can be a problem during the colder months when many people burn wood for heating.

If inhaled, carbon monoxide reduces the amount of oxygen carried by the blood. As a result, it can cause headaches, sleepiness, chest pains, brain damage, and death. Technologies such as catalytic converters in vehicles and industry convert carbon monoxide into carbon dioxide. Research is underway to develop improved and affordable catalyst materials that can better reduce emissions of carbon monoxide from vehicle exhausts and industrial facilities.

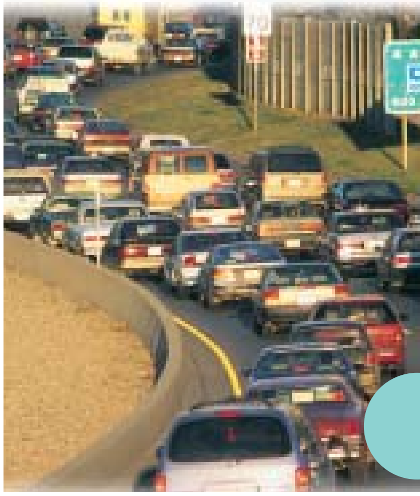


**Figure 2.13** Motor vehicles are the main source of the major air pollutants $NO_{x(g)}$, $CO_{(g)}$, and $O_{3(g)}$.

## Ground-Level Ozone

You read at the beginning of this section that a layer of ozone protects Earth's surface from harmful ultraviolet light. This layer is located high above Earth in the upper atmosphere. This same chemical—ozone—is also found at Earth's surface. But at ground level, ozone is a harmful pollutant. Ozone is an example of a chemical that may not be harmful and may even be beneficial in one situation. But in another situation, it may be a pollutant.

**Ozone** ($O_{3(g)}$) is an odourless, colourless gas composed of three oxygen atoms. At ground level, it forms from reactions between oxygen, nitrogen oxides, and compounds called volatile organic compounds (VOCs), in the presence of heat and sunlight. VOCs are organic chemicals that evaporate easily. Some plants and trees emit VOCs, but most of the VOCs come from human-made products such as solvents and gasoline.

The major source of ground-level ozone is fuel combustion in vehicle engines and industry. As a result, ozone pollution is a problem mainly in larger cities, especially during the summer. Some cities issue warnings on days where ozone levels are expected to be high so people with respiratory problems can stay indoors.

Ozone is especially harmful to people who have lung diseases such as asthma, and anyone with a cold. All children are at a higher risk than healthy adults because their lungs are still developing. Anyone who exercises outside in air containing high levels of ozone may suffer breathing problems and long-term lung damage.

Ground-level ozone can seriously affect crops such as wheat, soybeans, and onions. Ozone can also cause materials such as plastics to deteriorate more rapidly.

**reSEARCH**

**Catalytic Converters**

A catalytic converter is a device that uses platinum and palladium catalysts to remove pollutants from vehicle exhaust. Prepare a report on the chemical reactions that take place in a catalytic converter. Do they eliminate pollutants entirely? Begin your information search at www.pearsoned.ca/scienceinaction.

# CHECK AND REFLECT

### Key Concept Review

1. Match the chemicals that are components of air in column A with their correct percent composition in column B.

| Column A | Column B |
|---|---|
| oxygen | 78% |
| carbon dioxide | 21% |
| nitrogen | less than 1% |
| argon | 0.03% |
| hydrogen | trace |

2. Scrubbers use a chemical reaction to remove a major pollutant from the air.
   a) What pollutant is removed?
   b) What are the products of the chemical reaction?
3. Why is carbon monoxide harmful to animals?
4. Scientists have two main methods of determining the amount of pollution in the air. Explain why a) is a more accurate method than b).
   a) measuring the concentration of harmful chemicals in the air
   b) estimating the amount of harmful chemicals in emissions from industrial plants and other sources

### Connect Your Understanding

5. *Ozone can be both helpful and harmful.* Explain this statement.
6. Look at the graph in Figure 2.14. What trends do you see in the following sectors?
   a) total amount (top line)
   b) natural gas processing
   c) oil sands
   d) electric power generation

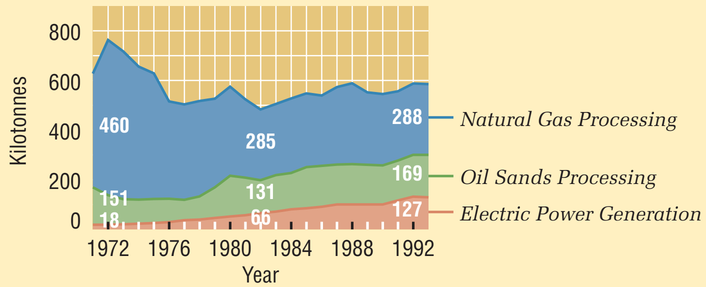



**Figure 2.14** Alberta sulfur dioxide emissions by sector for questions 6 and 7 (Graph supplied by Alberta Environment)

7. Look at the graph in Figure 2.14. Which process has contributed to a reduction in total sulfur dioxide emissions in Alberta since the early 1970s? Suggest a reason for this.

### Extend Your Understanding

8. a) Identify the harmful compounds in car exhausts and explain why they are harmful to the environment.
   b) Explain one benefit of catalytic converters.
   c) Explain why catalytic converters have become an issue for people concerned about global warming.

# 2.3 Monitoring the Atmosphere

Chemicals in the air can cause mild to serious health effects in local areas, but some chemicals in the atmosphere can affect the entire globe. Ozone depletion and climate change related to increased carbon dioxide concentration are both international issues.

## Carbon Dioxide as a Greenhouse Gas

Carbon dioxide is not considered a pollutant since it is naturally present in the air. However, the increasing amount of carbon dioxide in the atmosphere has become a concern for governments and an important area of study for scientists.

Each time you exhale you release carbon dioxide into the atmosphere. Each time your parents drive you to music lessons or hockey practice, the family car releases carbon dioxide into the atmosphere. When you have a bonfire at the lake to roast marshmallows, the fire releases carbon dioxide into the atmosphere. One person, one car, and one bonfire don't add much carbon dioxide to the air. But consider the huge amount of carbon dioxide added to the atmosphere by billions of people, millions of cars, and millions of fires worldwide.

Many people wonder what effect this large amount of additional carbon dioxide in the atmosphere may have on the planet. Investigations into this question are going on around the world.

### The Greenhouse Effect

Life on Earth thrives because we live in a natural greenhouse. Some gases in the atmosphere act like the glass in a greenhouse. They trap heat from the Sun's radiant energy. This heat keeps Earth at temperatures that allow living things to live, grow, and reproduce. The atmospheric gases that trap heat are called **greenhouse gases**. Water vapour, carbon dioxide, methane, and nitrogen oxides are all greenhouse gases.

*info***BIT**

**Canada's Chemical Contributions**

Canada has only 0.5% of the world's population, but we account for about 2% of human-caused carbon dioxide emissions, 2% of nitrogen oxide, and 1% of methane emissions.

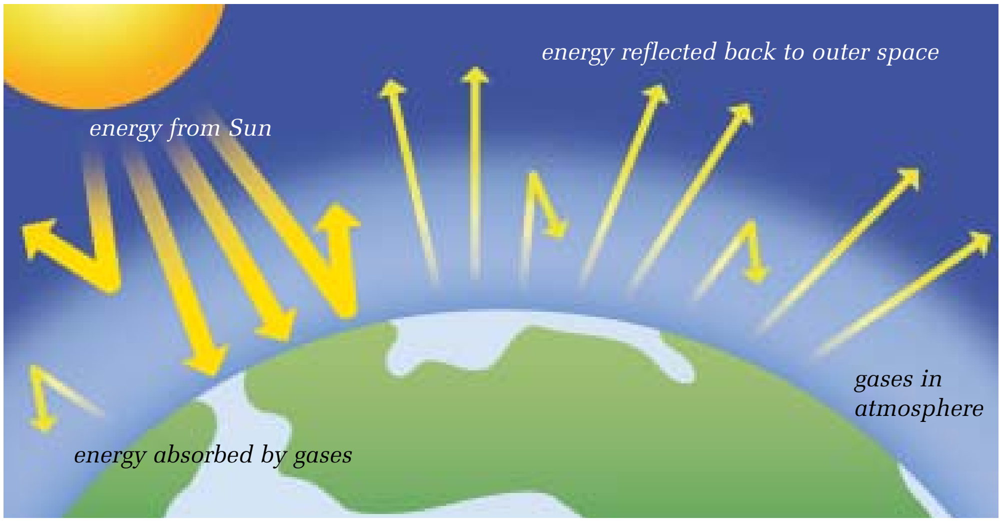



**Figure 2.15** The Greenhouse Effect: When radiant energy from the Sun reaches Earth's surface, much of it is reflected back into space. But some of this energy is trapped near Earth's surface by a layer of gases that act like the glass in a greenhouse.

## The Enhanced Greenhouse Effect

Many scientists support the theory that human activities such as burning fossil fuels and clearing land are contributing to an **enhanced greenhouse effect**. The enhanced greenhouse effect results from the greater concentration of gases trapping even more heat. In turn, this increases overall temperatures on Earth. This temperature increase worldwide is called **global warming**.

Global warming may lead to climate change, which could dramatically affect living things all over the world. These effects could include more violent storms, flooding of coastal areas from melting icecaps, and greater ranges in the spread of diseases.

After water vapour, carbon dioxide is the gas that contributes most to the enhanced greenhouse effect. Measurements of atmospheric carbon dioxide began late in the 1800s at various locations around the world. Over the years, more monitoring stations have been added. Data from these stations are continually being analyzed by scientists. Figures 2.15 and 2.16 show the difference between the greenhouse effect and the enhanced greenhouse effect.

**math Link**

In 1998, $SO_{2(g)}$ emissions in Canada measured 2696 kt. The national cap or prescribed limit was 3200 kt. Calculate the percent the 1998 amount was below the national cap.

## Global Warming

Scientists have concluded that global warming is taking place and that it is caused at least partly by human activities. Natural events such as volcanic eruptions and forest fires may also be part of the cause of global warming. Like some human activities, they may increase the concentration of greenhouse gases in the atmosphere.

Some countries have started to reduce carbon dioxide emissions. For example, windmill farms are being used to power turbines in order to reduce the amount of fossil fuel being burned. Some companies are investing in forest projects so that growing trees can absorb carbon dioxide and offset the company's carbon dioxide production.

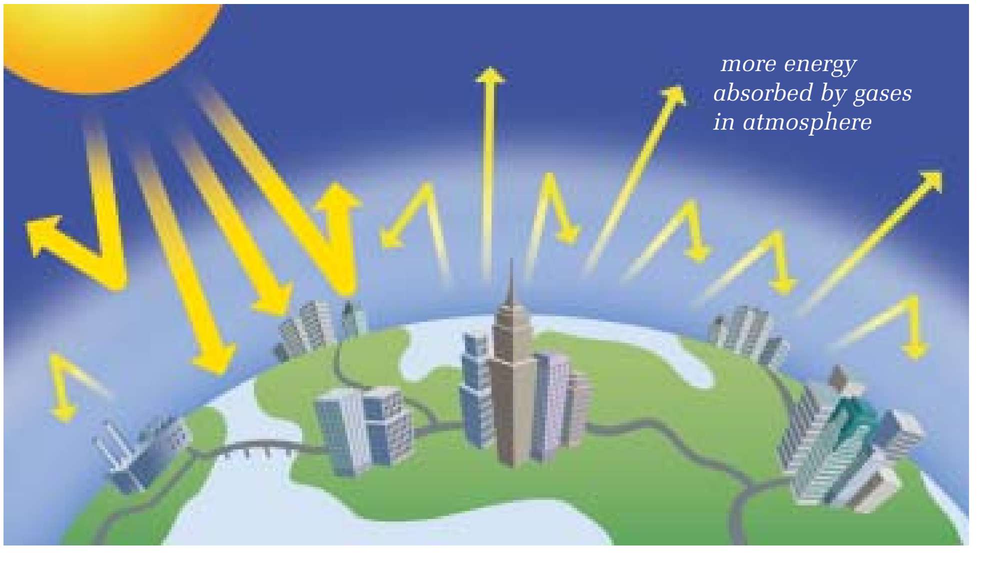



**Figure 2.16** The Enhanced Greenhouse Effect: Human activities are generating more greenhouse gases, so many scientists have concluded that more heat is being trapped. This means that Earth's surface temperature will continue to rise. This worldwide increase is called global warming.

ACTIVITY C-8

**Inquiry**

# ANALYZING CARBON DIOXIDE MEASUREMENTS

### The Question

What does monitoring information indicate about trends in amounts of atmospheric carbon dioxide?

### Materials & Equipment

- data sheet on $CO_{2(g)}$ concentration
- graph in Figure 2.18
- graph paper

### Procedure

TOOLBOX

1. Collect data sheets from your teacher that show tables of data on carbon dioxide concentrations recorded at Mauna Loa, Hawaii, and Point Barrow, Alaska.
2. On the same graph, plot two line graphs, one from the data in Table 1 and one from the data in Table 2. Use different colours or symbols for each graph. These graphs represent **monthly** $CO_{2(g)}$ concentrations.
3. Use the data provided in Table 3 to prepare a line graph of **yearly** $CO_{2(g)}$ concentrations measured each May at Mauna Loa only.
4. Look at the graph in Figure 2.18 as a guide. Use a different-colour pencil or pen to draw a line of best fit on your graph of yearly $CO_{2(g)}$ concentrations (step 3).

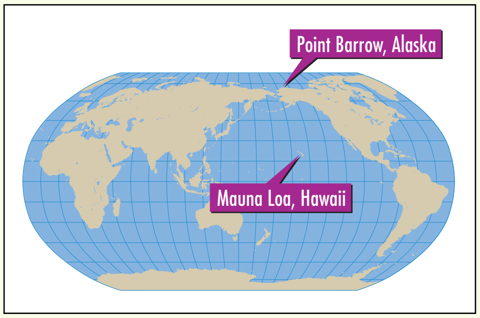



**Figure 2.17** Locations of Point Barrow, Alaska, and Mauna Loa, Hawaii

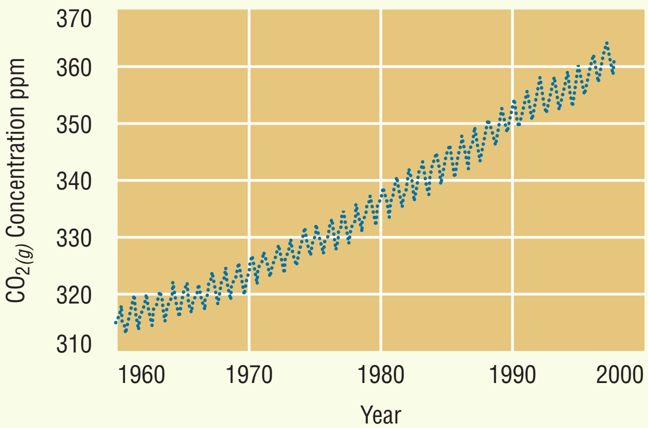



**Figure 2.18** Monthly atmospheric $CO_{2(g)}$ data recorded at Mauna Loa. Mauna Loa is a mountain in Hawaii.

### Analyzing and Interpreting

5. Look at the graph you prepared with the data from Table 1. What do you notice about the amounts of atmospheric $CO_{2(g)}$ over one year? Why do you think this occurs?
6. Is there any difference in the data from the two collecting sites? Why do you think this occurs?
7. Suggest a reason why Mauna Loa, Hawaii, and Point Barrow, Alaska, would be chosen as good sites to monitor atmospheric $CO_{2(g)}$.
8. What is the trend in the amount of atmospheric $CO_{2(g)}$ from 1974 to 1998, as recorded at Mauna Loa?

### Forming Conclusions

9. Refer to your graphs and Figure 2.18 to explain what monitoring information indicates about monthly and yearly trends in atmospheric $CO_{2(g)}$ concentrations.


**Figure 2.19** Scientists use ice cores from the Arctic and Antarctic to obtain information about $CO_{2(g)}$ concentrations over hundreds of years. Air is trapped as snow falls and held in ice as the snow builds up. Scientists drill down into the ice and take samples. They then analyze the $CO_{2(g)}$ content of the air bubbles in the ice.

## The Ozone Layer

In subsection 2.2, you learned about the dangers of pollution from ground-level ozone ($O_{3(g)}$). You also learned that this same chemical occurs high up in Earth's atmosphere, where it has an important function in protecting Earth's surface. This concentrated layer of ozone absorbs ultraviolet radiation (UV) from the Sun. By absorbing this radiation, the ozone layer protects organisms on Earth from damaging UV rays.

The ozone layer is a natural formation of ozone 15 to 50 km above Earth's surface. Scientists have been monitoring the ozone layer since the late 1970s. Over the years, they have noticed that this layer has become thinner, allowing more UV radiation to reach Earth's surface. Some areas are so thin that they are called "holes" in the ozone. This loss of ozone results in greater exposure to UV radiation on Earth's surface, which could have wide-ranging harmful effects on organisms. For example, the occurrence of human skin cancer and cataracts could increase. Plankton are sensitive to UV exposure, so increased UV radiation could cause plankton to die. This would affect all the animals that feed on plankton.

**reSEARCH**

**Enhanced Oil Recovery**

To reduce carbon dioxide in the atmosphere, carbon dioxide is being captured and injected into depleted oil reservoirs for enhanced oil recovery (EOR). Use books, magazines, or electronic sources to find out how EOR is done. Write a summary of the environmental and economic benefits of EOR. Begin your search at www.pearsoned.ca/scienceinaction.

### The Role of Chlorofluorocarbons

Scientists have concluded that the thinning of the ozone layer is caused by our use of chemicals called chlorofluorocarbons (CFCs). CFCs have been used in many different applications, including refrigerators, aerosol cans for products such as hair spray, and fire extinguishers. These chemicals move slowly from the lower atmosphere where we use them, up into the upper atmosphere. There, UV radiation breaks them down into substances, such as chlorine, that destroy ozone. Chlorine atoms react with the ozone molecules to form oxygen molecules ($O_{2(g)}$). One chlorine atom can remove 100 000 ozone molecules. You may have heard of the ozone hole over the south pole. The extremely cold temperatures in that area cause ice particles to form in the upper atmosphere. These ice particles speed up the reaction that removes the ozone molecules.

Many countries have recognized the danger to the ozone from the use of CFCs. They have signed international agreements on reducing their use of these chemicals. Monitoring substances such as CFCs is an important step in reducing their harmful impacts.

## CHECK AND REFLECT

### Key Concept Review

1. List four greenhouse gases.
2. International panels have been set up to study global warming and climate change. Describe three outcomes of global warming that are of concern.
3. a) What factor has contributed to the thinning of the ozone layer?
   b) What is happening as a result of this thinning?
4. What are countries doing to protect the ozone layer?

### Connect Your Understanding

5. What trend has been observed in carbon dioxide levels over the past century? Describe two suggested causes of this trend.
6. Explain the difference between the greenhouse effect and the enhanced greenhouse effect.
7. In which months would you expect the carbon dioxide levels to be lowest in Alberta? Explain why you chose those months.
8. Match the four statements below with the following fields of study: political, scientific, economic, or technological. Suggest one question for further study that could be asked in each case.
   a) Carbon dioxide levels have been measured and analyzed. They have been rising since the Industrial Revolution.
   b) Scrubbers use calcium carbonate (limestone) to remove sulfur dioxide from smokestack emissions.
   c) Governments limit and monitor emissions such as sulfur dioxide and nitrogen oxides.
   d) People are demanding inexpensive electricity. Removing pollutants from smokestacks is expensive. Who will pay for it?

### Extend Your Understanding

9. At Biosphere 2 near Tucson, Arizona, scientists are studying the growth of poplar trees in three different concentrations of carbon dioxide. Evidence suggests that slight increases in carbon dioxide levels stimulate plant growth. Why do you think this occurs?

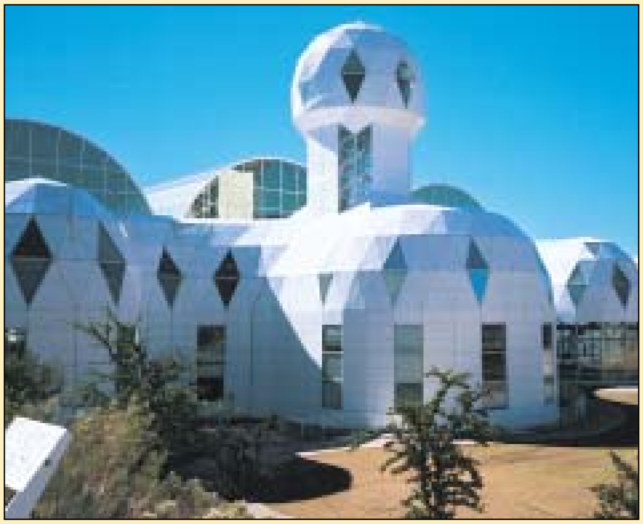


**Figure 2.20** Biosphere 2 is a closed ecosystem laboratory used to investigate ecosystem interactions. It contains five biomes—a rain forest, a desert, a savannah, a marsh, and an ocean. It is about 30 m tall at its highest point.

## Section Review

### Assess Your Learning

**Key Concept Review**

1. What do the presence of fish and a wide diversity of invertebrates in a river indicate?
2. Why is it important to have long-term measurements when studying ecosystems?
3. a) List six heavy metals that can be taken up by plants.
   b) Why are they considered pollutants?
4. Identify the organisms in Figure 2.21.

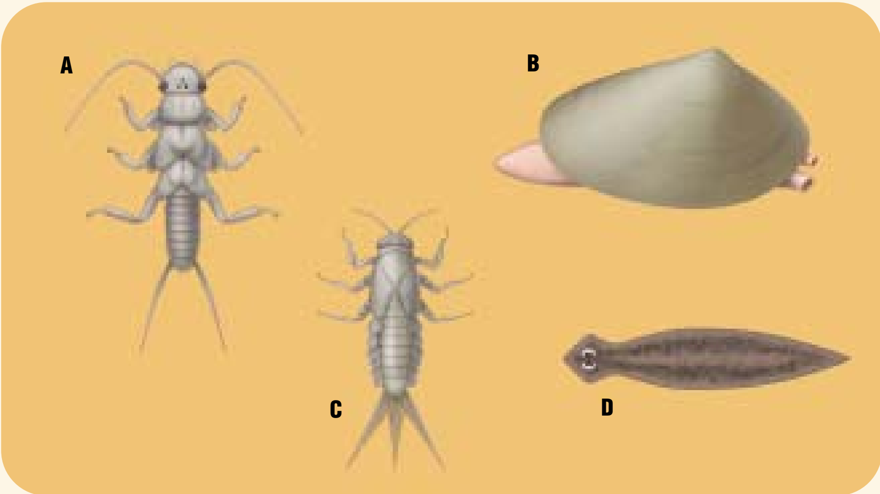



**Figure 2.21** Question 4

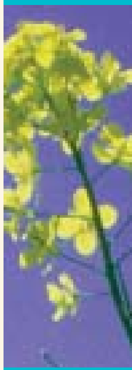
**Connect Your Understanding**

5. The table below shows monitoring data from two water systems.

| Characteristic | Sample A | Sample B |
|---|---|---|
| pH | 6.5 | 5.5 |
| Dissolved oxygen | 5.5 | 4.5 |
| Phosphorus | low | high |
| Nitrogen | low | high |
| Mayflies | present | absent |

Which statement below is correct?

a) Sample A indicates good water quality for aquatic life because there are low concentrations of phosphorus and nitrogen.
b) Sample A indicates poor water quality for aquatic life because there are many mayflies.
c) Sample B indicates good water quality because there are high concentrations of phosphorus and nitrogen.
d) Sample B indicates good water quality because the pH is basic and mayflies are absent.



6. You have an air sample that has 0.02 mL of carbon dioxide in 1000 mL of air. What is the concentration of the carbon dioxide in parts per million?
7. Describe two situations that reduce the dissolved oxygen content of water.
8. Match the words/phrases in column A with the descriptions in column B.

| A | B |
|---|---|
| LD50 | chemical used to kill insects |
| neutralize | to bring closer to pH 7 |
| insecticide | sudden lowering of pH |
| scrubber | measures toxicity |
| spring acid shock | removes $SO_{2(g)}$ |

9. Explain how the enhanced greenhouse effect may cause global warming.

**Extend Your Understanding**

10. Explain how the invention of the motor vehicle has been both beneficial and harmful.
11. How does reforestation affect the concentration of carbon dioxide in the air?

## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Science and technology are used to meet human needs and wants. However, they can have unintended consequences for both humans and the environment. In this section, you learned that monitoring chemicals in the environment is important because of both intended and unintended consequences. Consider the following questions, and use examples from this section to support your answers.

1. Pesticides are widely used in agriculture.
   a) What are the intended consequences of pesticide use?
   b) Give examples of some unintended consequences of pesticide use.
   c) How would monitoring be useful in helping to avoid some of the unintended consequences?
2. Spring acid shock is an unintended consequence of technology use. Suggest ways that technology could be used to reduce or eliminate this problem.
3. Explain why people are concerned about the rise in carbon dioxide levels over the past century.

# 3.0 Potentially harmful substances are spread and concentrated in the environment in various ways.

## Key Concepts

In this section, you will learn about the following key concepts:

- concentration and dispersal
- stability and biodegradability
- evidence of toxicity
- hazards, probabilities, and risk assessment

## Learning Outcomes

When you have completed this section, you will be able to:

- describe the transport of materials through air, soil, and water
- identify factors that may accelerate or retard the distribution of chemicals
- describe how the concentration of substances can be changed in the environment
- describe ways that biodegradation occurs and interpret information about the biodegradability of materials
- demonstrate how hazardous chemicals can affect the local and global environments
- identify potential risks resulting from consumer practices
- evaluate information and evidence related to an environmental issue

Just as balloons can be carried a long way on air currents, the molecules of potentially harmful chemicals can also travel long distances. For example, mercury can remain airborne for up to two years. The source of a pollutant can be in one country, but that same chemical may be deposited in another country—sometimes on the other side of the world. Chemicals carried in water also know no boundaries. It is easy to see why air and water pollution are global concerns.

In this section, you will learn how chemicals are transported in the environment through air, soil, and water. You will consider a case study that shows how a major oil spill can affect the environment. You will also learn more about handling and disposing of hazardous household chemicals safely.



For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

# 3.1 Transport of Materials Through Air, Soil, and Water

When pollutants are detected far from where they are produced, many questions arise. What is the source of a pollutant? Who is to blame for its spread? Who should pay to correct any environmental problems created by the pollutant? To help resolve these issues, scientists attempt to understand the transport paths of potentially harmful substances.

## Transport in Air

Figure 3.1 shows the three stages of transport of substances in air:

1. Release of the chemical at the source
2. **Dispersion** of the chemical in the atmosphere (the chemicals scatter in various directions)
3. Deposition of the chemical in soil or water

Sometimes, scientists must do a great deal of detective work to track down the source of a harmful airborne chemical. The direction and distance that airborne chemicals travel are determined by various factors. These include the pollutant's properties, the wind speed, and the direction of the prevailing winds. In Alberta, for example, the prevailing winds are from the west, so airborne substances are carried eastward.

The distribution of airborne pollutants may be limited by lack of wind. Precipitation is another factor that will affect distribution. An airborne pollutant will be deposited closer to its source if it is carried to the ground by rain or snow.

The source of a chemical that has travelled thousands of kilometres is usually impossible to identify. Often chemicals travel across borders, so deposition of airborne pollutants is an international problem. Many countries have signed international agreements and passed anti-pollution laws to limit the spread of airborne pollutants.

### *info*BIT

**Arctic Pollution**

Chemical pollutants called dioxins have been detected across Canada's north—even where no humans live. In one study, scientists used complex models of air transport to identify the sources of dioxins found in Nunavut. They found that most of those specific dioxins came from waste incinerators and metal processing facilities in the United States, and some came from Mexico!

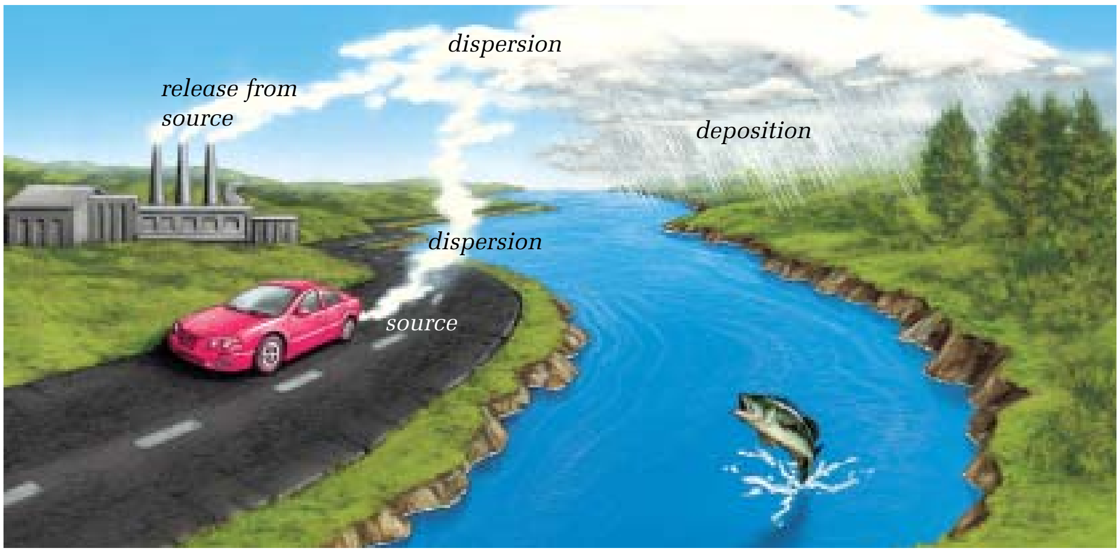



**Figure 3.1** The stages of atmospheric transport of chemicals

# QUICKLAB

## ENVIRONMENTAL TRANSPORT

### Purpose

To analyze movement of emissions in the environment

### Procedure

1 Look at the maps in Figure 3.2 and answer the questions below.

### Questions

2 Explain why sulfur dioxide emissions from the Alberta oil sands plants near Fort McMurray are a concern more for the people living in Saskatchewan than those living in western Alberta and British Columbia.

3 Explain why scientists consider sulfur dioxide emissions from a smelter in Trail, British Columbia, when they are studying environmental problems in Idaho.

4 Human-made chemicals have been found in Antarctica. How do you think they travelled there?


**Figure 3.2(a)** Fort McMurray, Alberta, and Trail, British Columbia

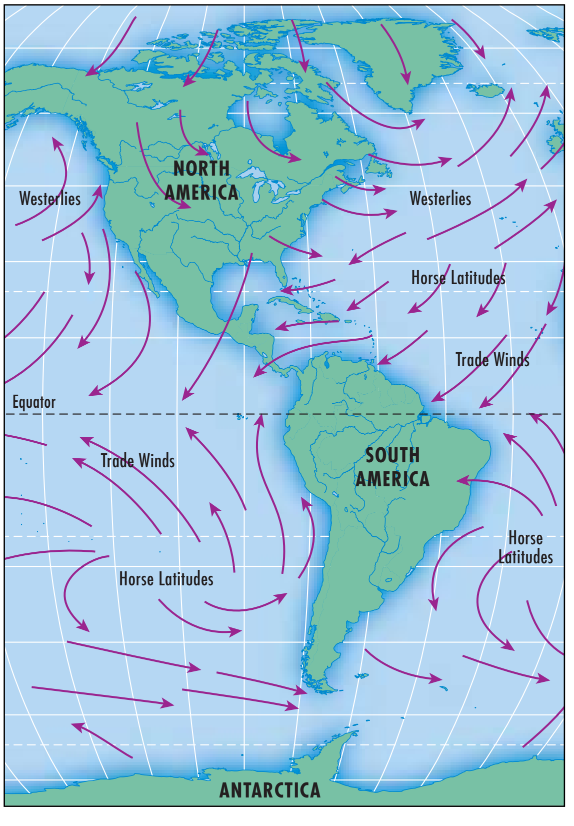



**Figure 3.2(b)** Surface winds

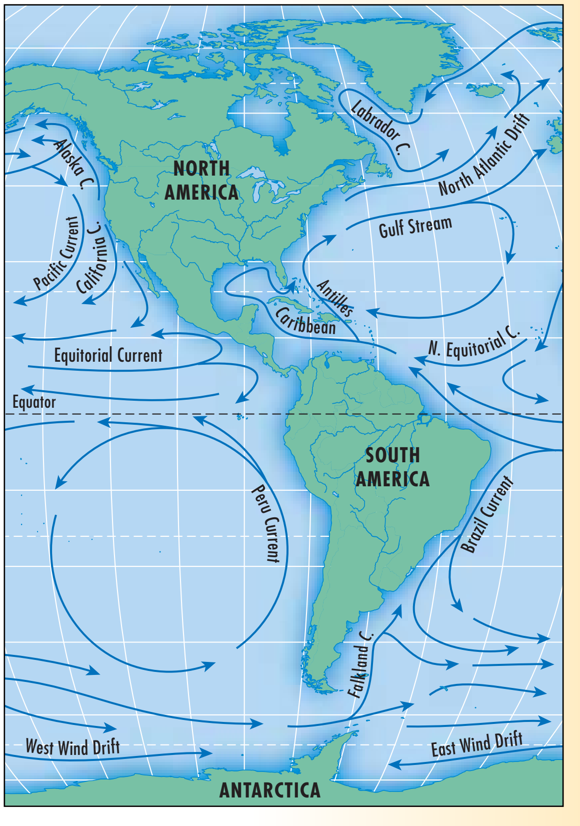



**Figure 3.2(c)** Ocean currents

### Transport in Groundwater

Water that soaks into soil moves first into a zone near the surface. Here the spaces between the soil grains contain both air and water. As the water moves deeper, it enters the next zone where all the spaces are filled with water. This water is called **groundwater**. The top of the groundwater zone is called the **water table**. If your home or school uses a well, you are drinking and washing in groundwater.

Groundwater can move sideways, up, and down. It can move as slowly as 1 m per year or as quickly as 1 m per day. But even its faster rate is much slower than that of rivers or streams. Because of groundwater's slow movement, contaminants such as lead cannot be quickly dispersed. They may become concentrated over time. This creates a problem if the contaminated groundwater is needed for drinking, agricultural purposes, or industrial use.

Factors that affect the movement of groundwater include the number and connection of pores in the soil. **Pores** are the tiny spaces between soil grains. Sometimes the soil grains are so tightly packed that the pores are not connected. In that case, water cannot move easily through the soil. If the pores are connected, water can flow through them. A **permeable** soil is one with interconnected pores. Pollutants will be transported farther by groundwater that flows through permeable soils.

The substances that contaminate groundwater occur either naturally or as a result of human activities. The table below gives examples of some of these contaminants.

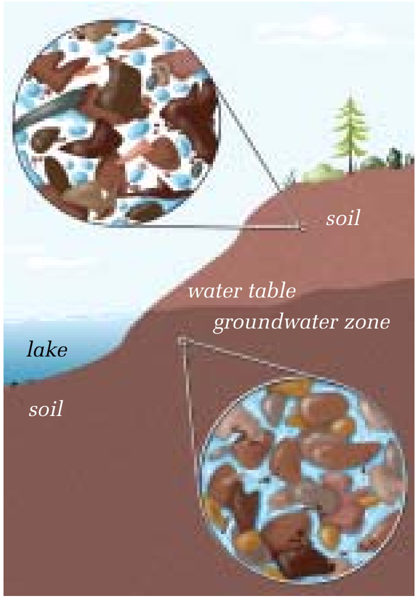



**Figure 3.3** The water table is the top of the groundwater zone. Below the water table, all the pores in the soil are filled with water.

**Some Substances That Contaminate Groundwater**

| Substance and Source | Examples |
|---|---|
| Minerals in rocks and soil | Iron, calcium, selenium |
| Organic substances occurring naturally or produced by humans | Pesticides, solvents, petroleum products |
| Substances leached from landfill sites and mine waste | Heavy metals (e.g., lead, mercury, cadmium), organic decomposition products |
| Substances that leak from underground storage tanks and pipelines | Gasoline, natural gas, oil |
| Inorganic substances from de-icing roads, agricultural and home use, industrial products, and vehicle exhausts | Salt, fertilizers, acidic deposition |
| Micro-organisms from improperly designed or maintained septic tanks and sewage treatment ponds, and improper storage and disposal of livestock wastes | Bacteria, viruses, protozoans |
| Household chemicals | Nitrates, phosphorus compounds, detergents, chlorine compounds |

Activity C-9

Inquiry

# Acid Rain and Soil

## Before You Start

In this activity, you will use vinegar to simulate acid rain. The liquid that has passed through the soil is called **leachate**.

### *Materials & Equipment*

- clay/loam potting soil
- sandy soil
- vinegar (diluted)
- graduated cylinder
- beakers
- funnel
- retort stand
- ring
- filter paper
- pH meter, chemical indicators, or pH paper

**Figure 3.4** Step 5

## The Question

What effect does the type of soil have on an acidic solution that passes through it?

## The Hypothesis

Restate the question above in the form of a hypothesis.

## Procedure

1. In your notebook, draw a table like the one below to record your observations.

| Sample | pH |
|---|---|
| | |
| | |
| | |

2. Fold and place a filter paper in a funnel. (Hint: Dampen the paper with tap water and it will stay in place.) Put dampened clay/loam soil into the funnel and tamp it down gently.
3. Support the funnel in a ring attached to a retort stand. Place an empty beaker under the funnel.
4. Measure 20 mL of diluted vinegar into the second beaker. Measure and record the pH of the diluted vinegar.
5. Pour the vinegar into the soil and collect the leachate. Measure and record the pH of the leachate.
6. Repeat steps 2 to 5 using the sandy soil.

## Analyzing and Interpreting

7. Which type of soil allowed the liquids to pass through more easily? Explain why.
8. Was your hypothesis correct? Explain why or why not.

## Forming Conclusions

9. Explain how the soil affected the pH of the leachate.

## Applying and Connecting

The pH of soil is important for plants because certain nutrients are available to plants only within a specific pH range. For example, phosphorus availability is best between pH 6.0 and 7.0. Ground limestone (calcium carbonate) can be added to acidic soil to make it less acidic. Adding peat or sulfur to basic soil will make it less basic.

## Extending

Design and carry out an experiment to answer this question: What amount of vinegar can pass through a soil sample before the neutralizing ability of the soil is reduced?

## Transport in Surface Water

Potentially hazardous chemicals can enter surface water systems from many different sources. These include the air, groundwater, runoff from agricultural fields and industrial sites, and outflow from storm sewers and sewage treatment plants. Chemicals from these sources may not be a problem if their concentrations are very low. They can be dispersed and carried away by the water. However, they may become a problem if the chemicals do not disperse, and the concentrations increase locally.

A substance that dissolves easily in water may be carried a long way and dispersed by the water. Some substances do not dissolve easily, and they may become attached to solids such as soil grains. In that case, they will not travel as far as dissolved substances. Instead, they will sink and become concentrated closer to the source. Substances that become attached to solids can build up in lake or river bottoms, affecting the organisms that live there.

Understanding the transport of chemicals in surface water is important to communities that obtain their drinking water from rivers, lakes, or artificial lakes called reservoirs. People who live in these communities are very careful about protecting their water sources. The water quality is monitored continually. Any contamination is tracked to its source whenever possible and eliminated or reduced.

## Transport in Soil

Water landing on a farmer's field or your front yard at home does four things:

- some evaporates
- some soaks into the soil and is taken up by plants
- some runs onto the street or into a stream
- some soaks through the soil and moves downward. As this water moves, it dissolves substances in the soil and carries them along. Such a liquid is called **leachate**.

The composition of soil can affect the rate at which a liquid moves through it. For example, you have learned in other science classes that water moves more easily through sand than through clay. Packed clay is impermeable—fluids cannot move through it because the soil grains are packed too closely. As you learned earlier in this unit, sanitary landfills are usually lined with a layer of impermeable clay. The clay prevents leachate containing harmful chemicals from moving into the soil and contaminating groundwater.

Some soils contain a large percentage of organic material, such as decayed leaves. This can slow the movement of chemicals if they are absorbed by the organic material. In some cases, the chemicals become attached to the soil particles, and their movement is slowed or stopped.

Hazardous materials can also be changed by chemical reactions that occur in the soil. For example, acids can be neutralized by substances such as calcium carbonate (limestone) in soil.

### reSEARCH

**Removing Phosphorus**

Phosphorus compounds can be removed from sewage water. However, the technology is expensive. Its use must be weighed against the environmental damage that the phosphorus might cause. Using books or electronic resources, prepare a report about the removal of phosphorus from sewage discharges. Begin your information search at www.pearsoned.ca/scienceinaction.

### Transport of Hydrocarbons in Soil

Contamination of soil by hydrocarbons is a problem at tens of thousands of sites across Canada. This contamination results from our daily use of hydrocarbons in vehicles and in industry, and from the extraction of hydrocarbons.

Some hydrocarbons are carried by water in the soil and can spread over a wide area. Others do not dissolve in water. These non-dissolving types of hydrocarbons may coat soil grains and completely fill the pores between the grains. This type of contamination does not spread very far from its source but is very difficult to clean up. It also creates high local concentrations of hydrocarbons. Most hydrocarbons are toxic to plants and animals (including humans).

## Check and Reflect

### Key Concept Review

1. State three reasons why an airborne pollutant might be deposited close to its source.
2. Suggest two ways that chemical pollutants could be carried far from their sources.
3. List four things that could happen to the water used in watering a local golf course.
4. Explain why airborne and water-borne chemicals are both local and global issues.

### Connect Your Understanding

5. Lead from a car battery has been detected in a lake far from where the battery was discarded and buried. How did the lead get there?
6. Explain how soil can affect the composition of the solutions that move through it.
7. Match the pollutant in column A with its possible source in column B.

| A | B |
|---|---|
| oil | rocks |
| acid rain | home gardening |
| bacteria | landfill |
| calcium | vehicle exhaust |
| leachate | sewage |
| pesticide | pipeline leak |

### Extend Your Understanding

8. One water well is located in sandy soil. Another water well is in soil that is mainly clay. Which well should be monitored more often? Why?
9. Many communities in Canada take their drinking water from rivers, lakes, or reservoirs. Why do they need to understand how chemicals are transported in surface water?

# 3.2 Changing the Concentration of Harmful Chemicals in the Environment

The best way to keep the environment safe is to prevent potentially harmful substances from entering it. However, this isn't always practical because most human activities introduce potentially harmful chemicals into the environment.

The concentration of pollutants in the environment can be changed using different techniques. The examples discussed here are: dispersion, dilution, biodegradation, phytoremediation, and photolysis.

**Dispersion** is the scattering of a substance away from its source. For example, suppose you are fertilizing your lawn and spill too much fertilizer in one spot. To prevent damage to the lawn in that spot, you could spread the fertilizer out over a larger area. In doing this, you would be dispersing the chemical.

**Dilution** reduces the concentration of a pollutant by mixing the polluting substance with large quantities of air or water. For example, if you place one drop of bleach into a sink full of water, the molecules of the bleach will mix with the molecules of water, and the bleach will be diluted.

A fast-flowing river or air mass can disperse and dilute a chemical very quickly. However, dispersion and dilution may not leave an area clean enough to meet government standards for clean water or air. Dilution or dispersion combined with another clean-up process, such as biodegradation, may be more effective.

*info***BIT**

**Biodegradation of a Chemical**

A site in Sarnia, Ontario, was contaminated with an organic chemical called ethylbenzene. Approximately 400 t of clay soil were dug up and placed in piles, and micro-organisms were added to the piles of soil. Within five months, concentrations of ethylbenzene dropped from 434 ppm to 25 ppm.

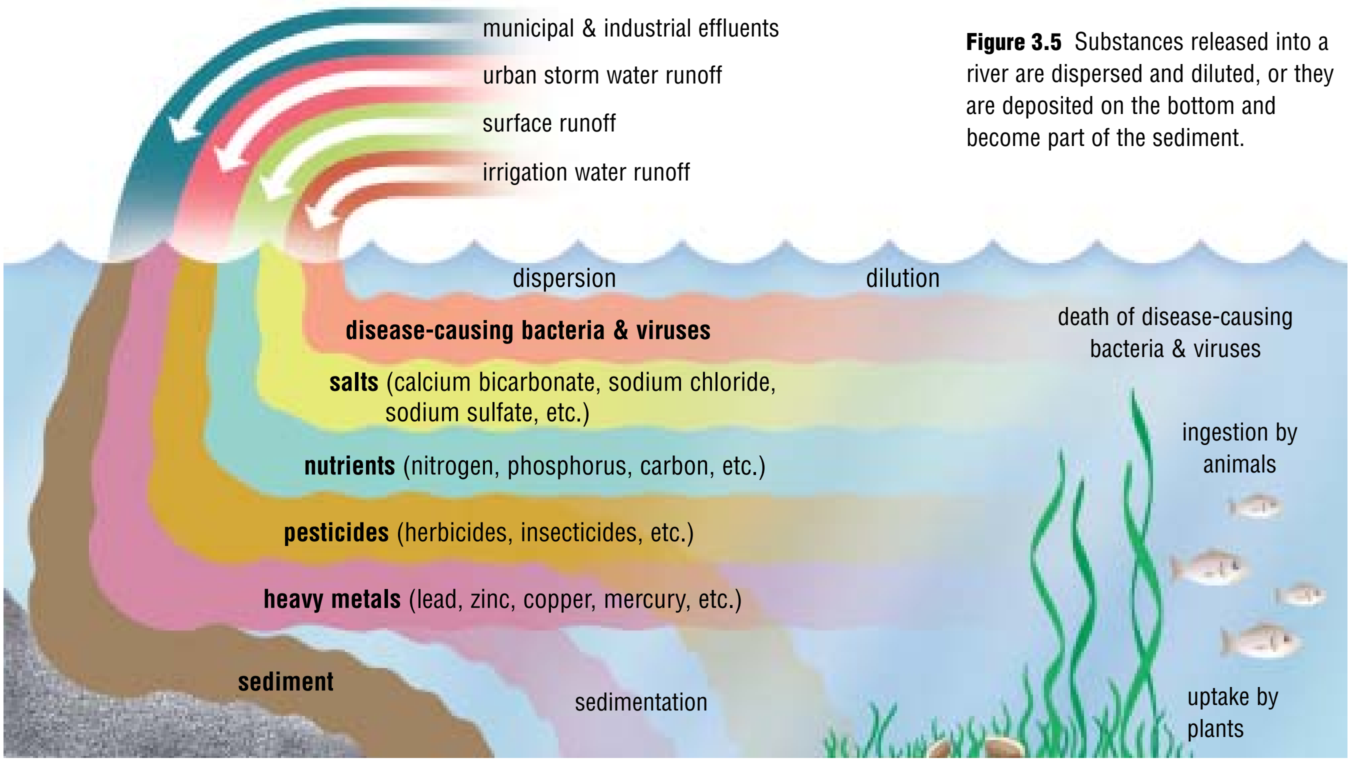



**Figure 3.5** Substances released into a river are dispersed and diluted, or they are deposited on the bottom and become part of the sediment.

## Biodegradation

Nature uses living things to clean the environment. Every autumn, leaves fall but they do not build up year after year because some of them decompose and become part of the soil. Organisms such as earthworms, bacteria, and fungi help the **biodegradation** of most organic substances, including many pollutants. “Bio” refers to living things and “degrade” means to break up.

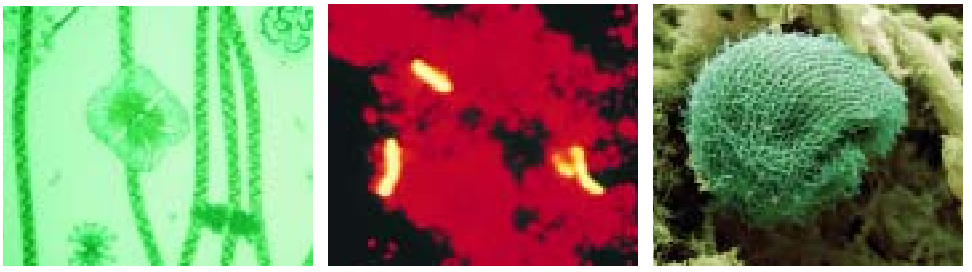


**Figure 3.6** Micro-organisms that live in or on the soil and water can be important in the biodegradation of pollutants. Left to right: algae, bacteria, a protozoan.

Micro-organisms are especially important in the biodegradation of pollutants. Many different types of micro-organisms live in soil and water. Algae, bacteria, fungi, and protozoa are common. Algae live at the soil surface and can produce their own organic compounds for food by photosynthesis. Bacteria, fungi, and protozoa use existing organic compounds for food. Carbon atoms in these molecules can be used to build biological compounds such as carbohydrates and protein.

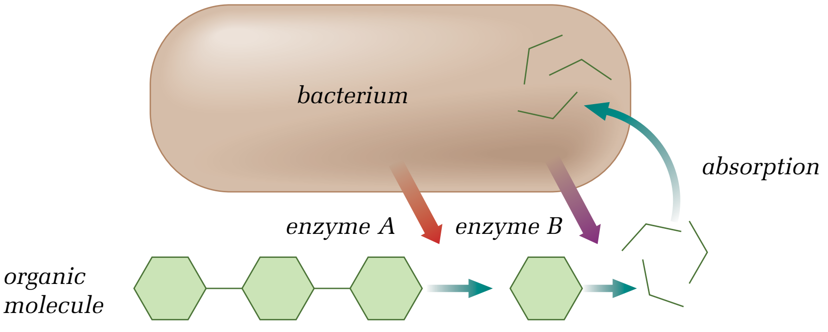



**Figure 3.7** Large organic molecules are broken down (hydrolyzed) either inside or outside bacteria. The decomposition process usually involves several steps.

### Bacteria

Each organism needs specific conditions to grow and reproduce. Some bacteria grow and reproduce only when oxygen is present. They use oxygen for the process of **aerobic** biodegradation (“aero-” means “air”). Some bacteria need an **anaerobic** environment—one without oxygen (“an-” means “without”). They thrive where there is little or no oxygen; for example, deep within landfill sites.

Some types of anaerobic bacteria remove chlorine from harmful chlorine-containing compounds such as PCBs (polychlorinated biphenyls). PCBs are human-made oils used in electrical equipment. These bacteria are able to remove chlorine atoms from the pollutant’s molecules and replace them with hydrogen atoms. The molecules can then be used as food for the bacteria. In this way, some harmful pollutants are removed from the environment.

ACTIVITY C-10

Inquiry

# BURY YOUR GARBAGE

### Before You Start

Each group in the class will select one variable to investigate and present their findings to the class.

### The Question

What effects do the following factors have on the rate of biodegradation of substances: moisture, temperature, surface area of pieces, type of waste?

***Materials & Equipment***

- soil
- large clear plastic party glasses
- apple pieces or other easily biodegradable material
- refrigerator for 1b)
- other waste material for 1d) (e.g., potato, paper, metal, plastic, cotton, nylon)
- balance
- ruler
- water
- sticks for markers

**Figure 3.8** Set-up for investigating factors that affect biodegradation

### Procedure

1. Your group will investigate one of the following questions:
   a) What is the effect of moisture on the rate of biodegradation?
   b) What is the effect of temperature on the rate of biodegradation?
   c) What is the effect of the size of garbage pieces on the rate of biodegradation?
   d) What is the effect of the type of garbage on the rate of biodegradation?
2. Controlling variables is important. As a class, determine the following before you begin:
   - size of the apple pieces
   - number of apple pieces
   - number of pieces of other types of garbage (for 1d) only)
   - amount of soil
   - amount of water that will be used to keep the soil moist
   - temperature of the set-up
   - location of the set-up
   - amount of time allowed for biodegradation
   - type of data to be collected before and after the apple pieces are buried
3. Record the following:
   - the question from step 1 that you will be investigating
   - the manipulated, responding, and controlled variables in your investigation
   - your hypothesis
4. With your group, plan your procedure and prepare a data table to record your group's observations. Show your procedure and data table to your teacher for approval before you begin. Carry out your experiment.
5. Prepare a data table to record the class results.

### Analyzing and Interpreting

6. Was your hypothesis correct? Explain why or why not.
7. What effect did the manipulated variable have on the rate of biodegradation in your investigation? Suggest reasons for this.
8. Present your data and your interpretation of this data to the class.
9. Did any other group in the class use the same variables as your group did? Were your group's results the same as theirs? Suggest reasons why or why not.

### Forming Conclusions

10. Write a summary of the results of your class's investigations. In your summary, describe the effect that the manipulated variables have on the rate of biodegradation. Suggest reasons for the class results.

### *re*SEARCH

**Pollution Clean-Up**

Using books or electronic resources, find and describe a situation where either biodegradation or phytoremediation has been successfully used to solve a pollution problem. Begin your search at www.pearsoned.ca/scienceinaction.

### Factors Affecting Biodegradation

In Canada, little bacterial growth occurs in the cold winter months, so biodegradation is very slow then, if it occurs at all. Temperature is just one factor that affects the rate of biodegradation. Other factors are soil moisture, pH, oxygen supply, and nutrient availability.

Bioreactor technology is a developing technology based on a knowledge of the effects of these factors. Bioreactors are designed to speed up the decomposition of organic wastes such as food and paper in municipal landfills. Liquids are added to the landfill to create ideal conditions for micro-organisms that decompose organic waste. Under these conditions, biodegradation occurs much more quickly.

Another method of encouraging biodegradation in soil involves planting vegetation. Bacteria and fungi occur in larger numbers in soil that contains plants than they do in soil without plants. The bacteria and fungi live around the roots of the plants. This greater microbial activity may increase the biodegradation of hazardous materials.

## PHYTOREMEDIATION

Green plants can also be used in another way to remove or degrade hazardous materials. **Phytoremediation** is a technique that can be used to reduce the concentration of harmful chemicals in soil or groundwater. "Phyto" means plant and "remediation" means correction or cure. Plants have been used to clean up metals, hydrocarbons, solvents, pesticides, radioactive materials, explosives, and landfill leachates. Some plants can absorb and accumulate (build up) unusually large amounts of metals from the soil. The plants are allowed to grow for some time and then harvested and burned or composted. In some cases, the metal can be recycled. Once the plants used for phytoremediation have "cleaned" the soil, other plants can be planted there.

**Figure 3.9** Sunflowers have been used at Chernobyl to remove radioactive substances from groundwater.

## Photolysis

Some substances degrade from exposure to light. **Photolysis** is the breakdown (lysis) of compounds by sunlight (photo). An example of photolysis is the formation of ozone. Nitrogen dioxide in the presence of light breaks down to form nitrogen monoxide and an oxygen atom. The oxygen atom then combines with an oxygen molecule to form ozone.

$$NO_{2(g)} \rightarrow NO_{(g)} + O_{(g)}$$

nitrogen dioxide → nitrogen monoxide + oxygen atom

$$O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$$

oxygen atom + oxygen molecule → ozone

Another example of photolysis is photodegradable plastic. Ordinary plastic does not degrade easily and can last for hundreds of years. Photodegradable plastic is made of chemicals that react when exposed to sunlight. After about three months, these reactions have changed the plastic to a fine powder that is easier to dispose of than the original plastic objects. The problem with photodegradable plastic is that it will not decompose if it's buried or placed anywhere else that sunlight cannot reach it.

## Check and Reflect

### Key Concept Review

**1.** List five ways of reducing the concentration of pollutants in the environment.

**2.** What element do bacteria remove from a PCB molecule?

**3.** How do micro-organisms change large organic molecules to forms that can be absorbed and used inside the cell?

**4.** Define and give an example of photolysis.

**5.** Cattails in swamps are used to absorb chemical pollutants. What method of reducing pollutant concentration is this?

### Connect Your Understanding

**6.** Would you rather live in an aerobic environment or an anaerobic one? Explain your answer.

**7.** Will a potato decay faster in warm soil or cold soil? Give a reason for your answer.

**8.** Are dispersion and dilution the same process? Explain.

### Extend Your Understanding

**9.** a) Suppose there was an oil spill in soil in a remote section of southern Canada. What would you suggest as an effective clean-up method? Give a reason for your answer.
b) Suppose the oil spill were in a sandy soil near a community water supply. What would you suggest as an effective clean-up method in this case?

**10.** Write the procedure for an experiment that would show the effect of pH on the rate of biodegradation of waste material.

*info***BIT**

**Lead in the Environment**

The City of Calgary issued a press release on May 17, 2001, stating that environmental monitoring results indicated that lead levels in surface soil in the Lynnview Ridge area were above the current environmental guidelines. Precautions were recommended. Lead can damage the kidneys, the nervous system, and the reproductive system. It is especially damaging to young children and fetuses.

# 3.3 Hazardous Chemicals Affect Living Things

So far in this unit, you have learned how chemicals can enter the environment, move through it, and be taken into organisms. You have also learned how harmful chemicals can be concentrated in the environment. For example, they can become concentrated in soil and river or lake bottoms. They can also accumulate in plants through uptake of water and nutrients. This increase in concentration means that some chemicals may remain in the environment for long periods. This also makes it possible for some chemicals to increase in concentration as they move up the food chain.

## BIOMAGNIFICATION

**Biomagnification** is the increase in concentration of a chemical or element as it moves up the food chain. A good example is mercury. Figure 3.10 shows what happens when mercury is introduced into the environment. The mercury comes from emissions from coal-fired power plants, waste incinerators, and commercial boilers and furnaces that burn mercury-containing materials. The mercury falls onto fresh or salt water where bacteria join it to an organic molecule that algae can absorb. Any one algal organism isn't affected by the mercury because it takes in very little.

At this point, the mercury enters the food chain when the algae are eaten by invertebrates such as insects. The mercury concentration is low in the algae because it is spread over many of them. But an insect has to eat many algae to survive. The insect is eaten by a fish, which has to eat many insects to survive. If these insects contain mercury, then the fish takes in a large quantity of mercury, which it stores in its body tissues. The fish may be affected by this concentration of mercury. Then you and your family catch several fish and eat them. If you eat enough of these mercury-contaminated fish, you may become ill. Mercury-contaminated fish have been a problem in parts of Canada, such as the Great Lakes.

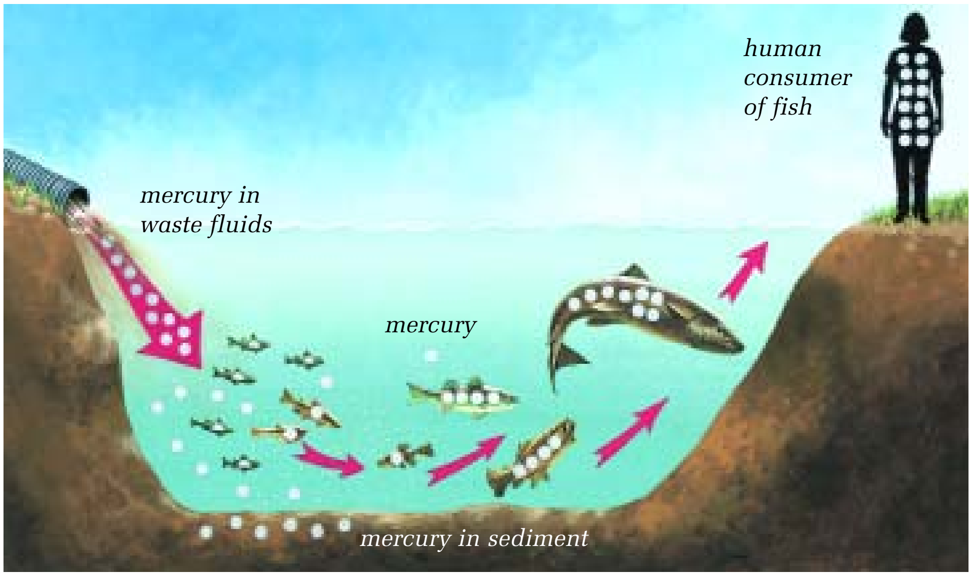



**Figure 3.10** Mercury can enter water systems in two ways. One way is from the air as a result of emissions from industrial plants. Another way is from industrial waste fluids, as shown here. Once in the water, the mercury increases in concentration as it moves up the food chain.

ACTIVITY C-11

**Decision Making**

# MOSQUITO CONTROL

## The Issue

In the spring, you look forward to playing baseball and having picnics in the park. To make your time outside more enjoyable, your city or town may use insecticides to kill mosquitoes. This cuts down or destroys the mosquito population so you don't have to be bothered by itchy bites. But such chemicals can harm other organisms in the environment. Should municipalities use insecticides to kill mosquitoes?

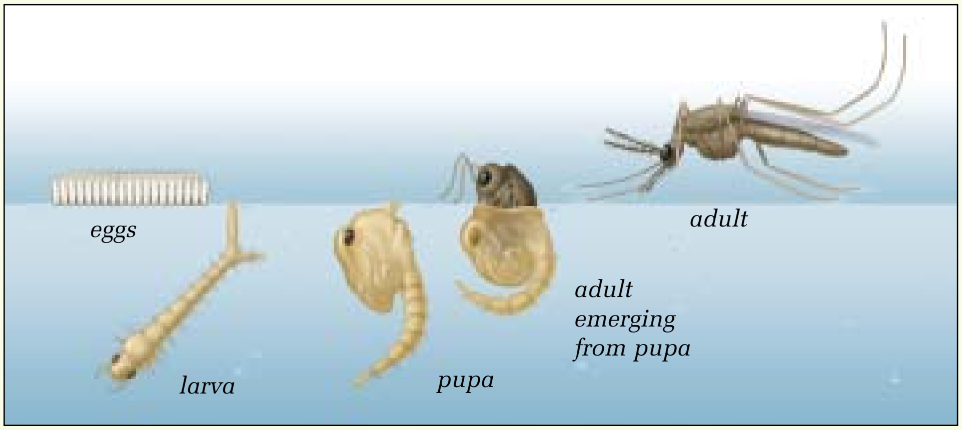



**Figure 3.11** Life cycle of the mosquito. Communities can monitor the mosquito larvae population in local water systems to gain useful information for deciding on a springtime insecticide program.

## Background Information

1. Every time an insecticide is used, it introduces chemicals into the local environment. These chemicals are carefully regulated (controlled by the government) to make sure they do as little damage as possible to the environment. However, an insecticide used to control mosquitoes may kill other species of insects as well, including those that eat mosquitoes.
2. Working with your group, research the benefits and costs of controlling mosquitoes with insecticides. Begin your search at www.pearsoned.ca/scienceinaction. Consider the following:
   a) the effect of mosquito populations on people's activities
   b) the potential for disease transmission by mosquitoes
   c) the effect of insecticides on other species besides mosquitoes. Remember to include effects on other members of the food web.
   d) alternative methods of mosquito control not using insecticides

## Analyze and Evaluate

3. With your group, design a presentation to summarize your group's findings. Be prepared to share your group's findings with the rest of the class.
4. Do you think insecticides should be used to control mosquitoes in your community? Give reasons to support your opinion.

## A Case Study: The *Exxon Valdez* Oil Spill


**Figure 3.12** Prince William Sound is on the south coast of Alaska.

Some chemicals in the environment have immediate short-term effects on organisms (for example, when a herbicide kills a weed). Some have longer-term effects through concentration and accumulation (for example, biomagnification of mercury). You will now have an opportunity to consider a case study of a chemical spill that had both short- and long-term consequences: the oil spill from the tanker ship *Exxon Valdez*.

In 1989, the *Exxon Valdez* went aground in Prince William Sound on the southern coast of Alaska. This huge tanker was carrying crude oil from Alaska to a refinery farther south on the west coast of the United States.

### Crude Oil

Crude oil is a mixture of many chemicals. It contains hundreds of different molecules in all shapes and sizes. For example, paraffin wax and asphalt are very large hydrocarbon molecules. Methane is a small one. Some molecules in crude oil contain atoms of nitrogen, oxygen, and sulfur. Metals such as mercury and lead may also be present. Crude oil cannot be used as soon as it is pumped from the ground—it must be processed in an oil refinery. There, it is heated and the chemical components are separated as they cool.

### Crude Oil Spills

Accidents happen. Loaded tanker ships can be accidentally driven onto reefs or rocky shores. Hazardous chemicals can change a beautiful setting. The beautiful setting of Prince William Sound changed when the *Exxon Valdez* spilled approximately 260 000 barrels (41 337 $m^3$) of crude oil into the sound.

The composition of oil changes after it is spilled. The lighter and smaller molecules disperse into the air or water. "Tar balls" of heavy hydrocarbons are washed ashore or sink into the sediment below the water. Bacteria are able to degrade some of this oil for use as food.

Long-term studies of oil spills, such as the one in Prince William Sound, have increased our knowledge of the impact of oil on the environment. It has been shown that some hydrocarbons are toxic in concentrations as low as 1 ppb, and that oil can persist in the environment for more than 10 years.

### Impact of the Oil Spill on the Environment

Oil from the *Exxon Valdez* spill covered thousands of square kilometres of water and polluted hundreds of kilometres of shoreline. A study done in 1992 estimated that 2% of the oil made it to shore. Most of it evaporated or dispersed into water. Ten years after the spill, bacteria and light had broken down much of the oil.

**Figure 3.13** The *Exxon Valdez* was a large oil tanker. Thousands of such tankers sail all over the world.

## Impact of the Oil Spill on Plants and Animals

Many different types of organisms were affected by the *Exxon Valdez* oil spill. Floating algae were killed. Invertebrates near shore could not survive the decreased oxygen, loss of food, and the toxic effect of the hydrocarbons. Fish eggs and young fish were especially sensitive to the toxic chemicals in oil. Pacific herring and pink salmon fry died or were physically deformed. Adult fish could avoid the oil by swimming away, but they lost habitat and food resources.

Seabirds and mammals became covered with oil. Oily feathers could not protect birds, and oily fur could not protect mammals such as sea otters from cold temperatures. It is estimated that over 30 000 birds and 5000 sea otters died because of the oil spill.

**Figure 3.14** Some oil-covered birds and animals were rescued and cleaned but many others died of the oil's effects.

## Impact of the Oil Spill on People

The *Exxon Valdez* oil spill also affected people who lived in the area. Many were commercial fishers, and now they could no longer fish. People who relied on wildlife for their food had to purchase more expensive groceries from stores. The tourist trade decreased dramatically as recreational users (campers and kayakers) chose not to come to the contaminated area.

## Clean-up and Restoration of Prince William Sound

Figure 3.15 shows that 14% of the oil was recovered. This was done by using skimming systems and containment booms. However, 10 years after the spill, oil still remained on some of the beaches.

Soon after the oil spill, the sediment near parts of the shoreline was removed and replaced with clean sediment. Those areas have recovered better than areas where the sediment was left in place.

Some birds and mammals were washed and kept in captivity for several days before being released. Most of these survived.

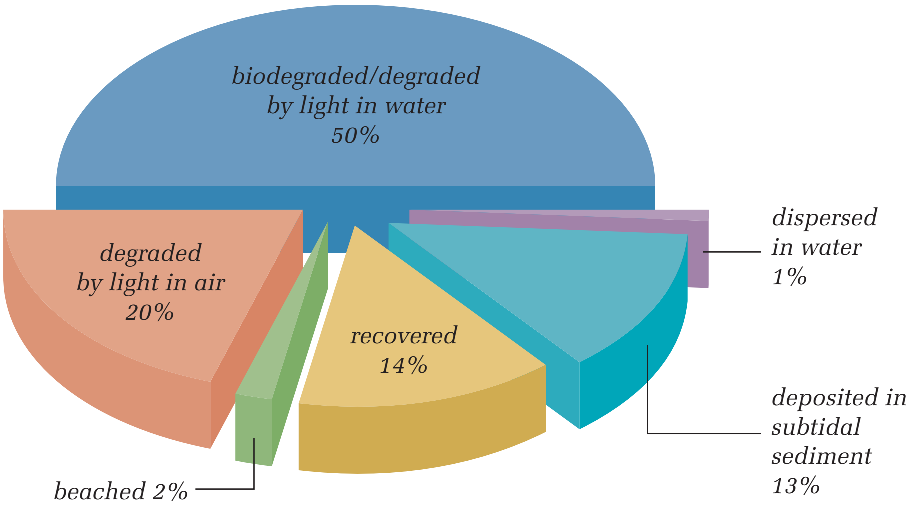



**Figure 3.15** This chart shows what happened to the spilled oil.

**reSEARCH**

**Hazardous Chemicals**

Select a hazardous chemical mentioned in this section or one approved by your teacher. Find out more about it by using books or electronic resources. Determine possible sources of the chemical, its effects on people and the environment, and how it can be removed or prevented from entering the environment. Prepare a multimedia presentation for the class about the chemical. Begin your search at www.pearsoned.ca/scienceinaction.

## New Oil Spill Clean-up Procedures

Oil spills and leaks can happen on land as well as on the ocean. Pipelines can rust and leak. Tanker trucks can spill their loads. Oil wells can blow out. Storage tanks can spill or leak. Since the large spill in Prince William Sound, government regulations have changed and new procedures have been put in place to deal more effectively with future spills.

In Alberta, companies are required to report spills greater than 2 $m^3$. Companies and governments have emergency response plans in place. Hands-on training for people working with oil and gas takes place yearly. These training sessions demonstrate effective techniques for controlling and cleaning up spills.

**Figure 3.16** Booms can be used to contain oil spills and help with clean-up.

## Check and Reflect

### Key Concept Review

1. Use an example to explain the term “biomagnification.”
2. List five ways that the *Exxon Valdez* oil spill affected Prince William Sound.
3. a) Look at Figure 3.15 on page 251. What percent of the oil was degraded by light after evaporating into the air?
   b) What percent of the oil reached the shores in Prince William Sound?

### Connect Your Understanding

4. Describe two ways that chemicals can become concentrated or build up in the environment.
5. Explain why using pesticides to kill mosquitoes has become an issue.
6. Suggest two reasons why some chemicals remain unchanged in the environment for a long time.

### Extend Your Understanding

7. Imagine that you are a newspaper reporter summarizing the *Exxon Valdez* oil spill. Write your report using the following headings:
   - what happened
   - the results
   - the clean-up
   - the after-effects (e.g., technology, government regulations)

# 3.4 Hazardous Household Chemicals

Housecleaning and gardening can be hazardous to your health. Products that we purchase for use in housecleaning, home improvement, gardening, and car maintenance may contain chemicals that could harm us or the environment. Hazardous household chemicals include:

- household cleaners
- personal hygiene products
- pet-care products
- paint and paint products
- pesticides and fertilizers
- automotive fluids

Estimates indicate that the average North American house contains between 12 L and 40 L of hazardous products. Improper transport, storage, and disposal of these products can contribute to health problems such as burns, heart, kidney, and lung ailments, cancer, and even death. We can use these products safely by paying attention to the information on labels and in fact sheets about them.

> **infoBIT**
>
> **Dishwasher Detergents**
> Poison control centres report that dishwasher detergents are the number one cause of child poisonings. Many dishwasher detergents contain very concentrated chlorine in a dry form.

## Government Regulations

TOOLBOX

Government regulations are designed to protect consumers and reduce the risks of transporting, storing, using, and disposing of hazardous materials. The regulations reflect the information available from scientific research done on these products. Such research considers not only the effects of a product alone, but also its interactions with other products. The regulations are reviewed and modified when scientific research provides new information.

As students working in a school, you must be familiar with the **Workplace Hazardous Materials Information System (WHMIS)**, set up by the federal government. WHMIS provides information on hazardous materials used in the workplace. Anyone who works with or must be near hazardous products must be familiar with WHMIS symbols and labelling, and with **Material Safety Data Sheets (MSDSs)**.

### Labels

If a potentially hazardous chemical is being transported, stored, or used, it must be labelled to alert workers to the dangers of the product and to provide basic safety precautions. There are different labels for different purposes: transport, supply, use in the workplace, and disposal. As students, you will be reading workplace labels that will include the name of the chemical and information on safe handling.

The labels on goods that you buy in a store for home use are covered by regulations as well. Figure 3.17, on the next page, is an example of a consumer goods label. You have seen WHMIS labels in earlier studies. For more information on WHMIS and other hazardous products labels, see Toolbox 1.

## GIVE IT A TRY

### Using a Hazardous Product

Suppose that you have been hired by your neighbours to apply wood preservative to a fence that surrounds their property. A vegetable garden is close to the fence, and a small stream runs near the fence at the back. Wood preservatives contain fungicides that protect wood from destruction by fungus (mildew) and insects. The wood preservative you will use is an arsenic compound that can be harmful to humans and other organisms, both on land and in the water. Figure 3.17 shows the information provided by the manufacturer on the product's label.

*Use Limitations*
- Use on exterior surfaces only.
- Use only above ground.
- Keep away from water systems since product is toxic to fish.

*Directions for Use*
- Be sure to have a clean dry surface before you apply this product.
- Use a brush to apply. Do not spray.
- Use full strength. Do not dilute.

*Precautions*
- Avoid breathing vapours.
- Keep away from open flames or sparks.
- Avoid skin contact.
- Wash with soap and water after using this product.

*First Aid*
- If swallowed do not induce vomiting. Call a doctor or a poison centre immediately.
- If spilled on skin, wash with vegetable oil followed by soap and water.
- If splashed in eyes, flush eyes with water for 15 minutes.


**Figure 3.17** Information about the wood preservative

- What clothing would you wear while applying the wood preservative?
- What tools and materials would you need for the job?
- List four precautions you would take while using the preservative.
- Suppose that several years after you put the preservative on the fence, your neighbours decide that they don't need all of the fence. They plan to burn the unwanted wood in their fire pit where they have wiener roasts. What advice would you give them?

### MSDS

All suppliers of potentially hazardous materials will provide the buyer with additional information about their products. This information is found in a Material Safety Data Sheet (MSDS). The MSDS gives a detailed description of the product—its composition, physical appearance, and chemical characteristics. The MSDS also describes the precautions that should be taken when handling, using, transporting, and disposing of the product. And it provides details of health effects, first aid treatments, and spill procedures. You should know where the binder containing the MSDSs is kept in your school.

## New Product Regulations

Certain types of products, such as pesticides, require government approval before they can be sold. Companies applying for product approval must follow a strict testing process according to government legislation. They must also provide detailed information that includes:

- intended use, physical and chemical properties, active ingredient(s)
- instructions for use, safety precautions
- health effects, environmental effects, toxicity to humans, and first aid instructions in case of poisoning


**Figure 3.18** Examples of hazardous household chemicals

## Storage of Hazardous Chemicals

The safe storage and use of chemicals prevent accidents and injury. Here are some safe storage suggestions:

- Leave all products in their original containers with the label intact.
- Keep all products in a location not accessible to children. If possible, keep hazardous products locked up.
- Be sure all containers are in good condition and have secure lids.
- Store products in a cool, dry, ventilated place away from pilot lights, stoves, and water heaters. If you can smell a household product that is in storage, the lid may be loose or ventilation may not be adequate.
- Never store flammable liquids and gases in glass containers—they might break. Store gasoline in a metal container with a safety cap, or a red plastic container approved for use with gasoline. Keep it outside the house in a storage shed. Never store propane inside the house because a leak can cause an explosion.
- Store corrosive, flammable, reactive, and poisonous products on separate shelves or in separate locations. Toilet and drain cleaners are examples of corrosive substances. Keep acids and bases separate from each other.
- Do not store oxidizers such as hydrogen peroxide, pool chemicals, and some fertilizers near flammable liquids. Oxidizers can cause other substances to burn.
- Place products in their storage areas so that they cannot fall over.
- Always return a hazardous product to its storage place when you have finished using it.
- Safely discard hazardous substances that are old or not needed.
- If a container is rusting or leaking, place it inside a second, secure container. Dispose of both containers together at a household hazardous waste collection site.

Activity C-12

Inquiry

## Household Chemicals and the Environment

### The Question

What effect do household chemicals have on the germination of radish seeds?

### The Hypothesis

Reword the question in the form of a hypothesis.

***Materials & Equipment***

- 10% and 50% solutions of household bleach
- 10% and 50% solutions of window cleaner containing ammonia
- 10% and 50% solutions of rubbing alcohol
- water
- graduated cylinder
- 4 small plastic bags
- marking pen
- 4 paper towels
- 20 radish seeds
- thumbtacks, pins, or tape

**Caution!**
Handle bleach, window cleaner, and rubbing alcohol very carefully. Bleach is corrosive. It can also take the colour out of your clothes.

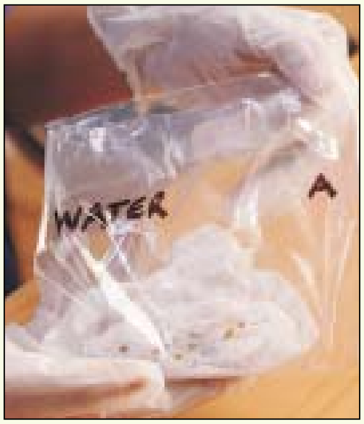



**Figure 3.19** Determining the effect of household chemicals on radish seeds

### Procedure

1. Using a marking pen, label 4 small plastic bags: one each for water, bleach, ammonia, and rubbing alcohol. Place your name or group symbol on each bag.
2. Crumple a paper towel and place it in the bag labelled "water."
3. Place 10 mL of water in the labelled bag. If that is not enough to moisten the paper towel, add more water. (The bottom of the bag should have a little extra water in it.)
4. Put 5 radish seeds into the bag. Place them between the plastic and the paper towel so that you will be able to see the seeds easily.
5. Repeat this procedure with one concentration of each household product. (Another group will use the other concentration.) Be sure to use the same amount of liquid in each bag.
6. Using tacks, pins, or tape, attach the bags to a bulletin board.
7. At the end of 5 days, count and record the number of seeds that have germinated in each bag.
8. Obtain the data for all the household products from other groups in the class.
9. Follow your teacher's instructions for disposing of all substances you have used.

### Analyzing and Interpreting

10. Why did one bag contain only water?
11. Which product had the greatest effect on the radish seeds?
12. Did different concentrations of the same product affect the radish seeds differently? Explain your answer.

### Forming Conclusions

13. Describe the effect of household chemicals on radish seeds.

## Transportation of Consumer Goods

There are two times when you or your family transport hazardous household materials:

- when the product is first bought
- when the unused portion of the product or the waste from it is taken to a hazardous waste collection site

In both cases, care should be taken to protect people in the vehicle from toxic fumes or spills from the containers. At all times, hazardous products should be kept out of the reach of children and family pets.

The hazardous materials should be placed in the trunk of the car or the box of the truck. Care must be taken that the containers stand upright and do not move.

When transporting hazardous household wastes to a collection site, never mix them together in one container. Mixing chemicals may cause a chemical reaction that results in an explosion or a poisonous product. The products should be left in their original containers with the labels intact so that the people at the collection site know how to process them.

## Disposal of Hazardous Chemicals

Never pour hazardous wastes down a drain or into soil. And never throw them away in the garbage. Hazardous wastes poured down a drain go into public sewer systems or septic tanks.

Occasionally, sewage treatment processes are not effective in removing some hazardous chemicals. If that happens, the chemicals are accidentally released to surface water. There they may harm aquatic organisms or end up in someone's drinking water. In a septic system, hazardous substances may harm the organisms that break down wastes. As a result, the system won't function properly, and pollutants may pass unchanged into the surrounding soil and water.

Disposing of hazardous household products by pouring them into the soil or putting them in the solid waste garbage can contribute to contamination of drinking water, soil, and even air.

## Hazardous Waste Collection Sites

Hazardous waste collection sites can be found in almost all Alberta communities. Wastes such as paints and fertilizers can be taken to these sites for disposal. Materials that cannot be recycled are safely packaged into larger containers. They are then labelled according to government regulations, and transported in labelled trucks with trained drivers to incineration plants.

**Figure 3.20** A hazardous waste collection site

## Solid Waste Garbage

Solid waste—what we usually call garbage—goes to a landfill site (unless it can be recycled). At the landfill site, some garbage may burn, explode, give off fumes, or be leached out. Leachate could potentially enter groundwater if it escapes from the protective plastic or clay liners of the landfill site.

Before you put something into the garbage, think about the following guidelines for safe disposal of household hazardous products:

- Take antifreeze to a recycling centre if one exists in your community. If recycling is not possible, dilute antifreeze well before pouring it down a drain connected to a sewage system. Seal the empty container before putting it into the garbage. Never pour antifreeze on the ground or down a drain connected to a septic tank.
- Take automotive products such as gasoline and oil to a hazardous waste collection centre. Oil can be recycled.
- Never place car batteries in a home garbage because they usually contain lead and sulfuric acid. Batteries can be recycled.
- Use up bleach according to directions on the container. Never pour it down drains because it might mix with acids or ammonia and create fatal toxic fumes.
- Use up cleaners and polishes. The empty containers should then be sealed before being thrown in the garbage.
- Use up corrosive products such as drain cleaners completely according to the directions on the container. Dilute very small amounts of drain cleaners in large quantities of water so that it is safe to pour the diluted mixture down the drain.
- Take fertilizers and pesticides to a hazardous waste collection site.
- Take leftover paint and paint products such as paint thinners, turpentine, and varnish to collection sites where they may be recycled. For empty paint cans, remove the lids so the remaining paint will dry before you put the cans in the garbage.
- Pack syringes in rigid containers and take them to collection sites.
- Empty aerosol containers completely so that they will not explode in the garbage. In a well-ventilated area, turn the container upside down with the nozzle facing a paper towel or other absorbent material. Depress the nozzle until the spray loses pressure.

**Figure 3.21** How to empty an aerosol can before placing it in the garbage

### reSEARCH

**Household Hazardous Material**

Select a household hazardous material for study and use labels, books, personal interviews, and electronic resources to find out more about it. Look for the following information: active chemical ingredient(s), instructions for use, first aid suggestions, safe storage ideas, and disposal of leftover product or containers. Create an information poster about the material. Begin your information search at www.pearsoned.ca/scienceinaction.

## Check and Reflect

### Key Concept Review

1. List five household chemicals that have the potential to be harmful.
2. What is WHMIS and why was it set up by the government?
3. List five ways you can prevent accidents when using or storing hazardous household chemicals.
4. Explain how the following products should be stored:
   a) gasoline
   b) toilet cleaner
   c) bleach

### Connect Your Understanding

5. Sodium hydroxide solution (pH 10.3) is used in school experiments. Explain the proper way to:
   a) handle it
   b) store it
   c) dispose of it
6. Explain two reasons why it is important to take leftover fertilizers and pesticides to collection sites.
7. Use the product label in Figure 3.22 to answer the following questions:
   a) What does the warning symbol represent?
   b) What are the names of the active ingredients?
   c) What is the intended use of this product?
   d) Describe the directions that must be followed before and during use.
   e) How can this product enter your body?
   f) Why should this product be kept away from ponds and streams?

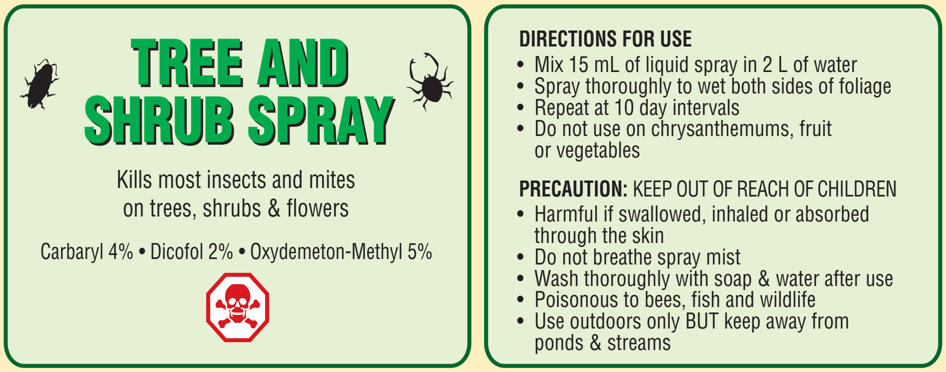



**Figure 3.22** Product label for question 7

### Extend Your Understanding

8. You are helping to clean the garage, and you come across a substance in an old container without a label. Your brother suggests dumping it down the drain.
   a) Why is this not a good practice?
   b) What is a safer method of disposal?

# Section Review

## Assess Your Learning

### Key Concept Review

**1.** Why is it important for pollution chemists to know about prevailing winds?

**2.** Match the words in column A with their synonyms or definitions in column B.

| Column A | Column B |
|---|---|
| dispersion | degradation caused by light |
| dilution | scattering |
| biodegradation | break up by living things |
| photolysis | reduction in concentration |

**3** Why should an aerosol container be completely emptied before it is discarded?

**4.** You have designed a new insecticide. In order for your new insecticide to be sold to the public, what information would be required by government regulations?

**5.** Describe three factors that affect biodegradation.

### Connect Your Understanding

**6.** Explain why you must be very careful when storing oxidizers such as hydrogen peroxide.

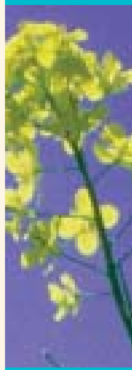
**7.** Why is it bad practice to throw household chemicals such as bleach on garden soil?

**8** Look at Figure 3.23. Some hazardous household products are being transported in an unsafe manner. List as many things as you can that are wrong or unsafe in this picture. Then suggest better, safer ways to transport or handle these products.


**Figure 3.23** Question 8

**9.** Why is it important that chemicals used in the classroom be labelled?

**10.** What types of information are found on MSDS documents?



**Extend Your Understanding**

11. Choose two of the substances listed below and write a paragraph or draw a series of pictures to show how each affects living things.
    nitrogen compounds
    mercury
    oil
    selenium

12. An old gasoline storage depot is torn down, and the land is used for a children's playground. Later, it is discovered that the soil in the playground is contaminated with lead. What clean-up program would you suggest to the town?

13. Suppose that you have just finished using a poisonous zinc solution to preserve a wood deck.
    a) How would you dispose of the leftover product and the tools that you used? Are there any risks in the method that you chose?
    b) If the leftover product were going to be stored, how and where would you suggest storing it?

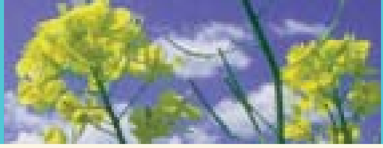
## Focus On SOCIAL AND ENVIRONMENTAL CONTEXT

Chemicals exist naturally everywhere on Earth. However, human activities can introduce other potentially harmful chemicals to the environment. Decisions on developing and using chemicals should be based on a variety of considerations. These include social, environmental, ethical, and economic concerns. Answer the following questions, and use examples from this section to support your answers.

1. Write a statement that expresses an economic viewpoint in favour of few restrictions on the transport of crude oil.

2. Write a statement that expresses an environmental viewpoint in favour of strict government controls on the transport of crude oil.

3. Testing indicates that the soil in a new subdivision is contaminated with lead. Identify the types of viewpoints expressed in the following comments made by residents in the area. (Hint: Are they worried about health, economic considerations, the environment, ethics?)
   a) "I am worried about my three young children developing serious nerve problems."
   b) "I think that the people responsible for the lead problem should pay for the clean-up."
   c) "I am very concerned about property values going down."
   d) "I think that more testing should be done so that all of the problem areas can be identified."
   e) "My family is interested in finding out the various methods that can be used to reduce the concentration of lead."



# Unit Summary: Environmental Chemistry

| Key Concepts | Section Summaries |
|---|---|
| **1.0**<br>• chemicals essential to life<br>• organic and inorganic material<br>• acids and bases<br>• ingestion and absorption of materials<br>• substrates and nutrients | **1.0 The environment is made up of chemicals that can support or harm living things.**<br>• Chemicals form everything in the environment—both living and non-living things.<br>• Pollution is any change in the environment that produces a condition that is harmful to living things. It can result from human activities or other events (e.g., volcanoes).<br>• Acids and bases occur naturally or as a result of human activities. Acids have a pH below 7. Bases have a pH greater than 7. A substance with a pH of 7 is neutral. Some acids and bases can neutralize each other. Never mix acids and bases unless you know it is safe to do so.<br>• Common substances are needed by plants and animals for healthy growth. Carbon, oxygen, and hydrogen are the most common elements in living things.<br>• Organic molecules such as carbohydrates contain carbon. Inorganic molecules, such as many minerals, generally do not contain carbon.<br>• Plants use inorganic substances to produce organic molecules such as carbohydrates, lipids, proteins, and nucleic acids. Consumers rely on producers for their food.<br>• Organisms require optimum amounts of nutrients for good health.<br>• Plants take in substances through their roots by osmosis and active transport. Animals, including humans, ingest food and absorb nutrients into their blood.<br>• The environments and substrates where organisms live affect the availability of nutrients. |
| **2.0**<br>• air and water quality<br>• concentration and dispersal<br>• uncertainties in environmental monitoring and in assessing toxicity and risk | **2.0 The quantity of chemicals in the environment can be monitored.**<br>• Guidelines for water quality help to protect humans, animals, crops, and other organisms that live in or near water systems.<br>• Concentrations of chemicals in the environment are usually measured in parts per million.<br>• Water quality can be measured using biological and chemical indicators. Invertebrates are often used as biological indicators. Examples of chemical indicators include the amount of dissolved oxygen, phosphorus, and nitrogen.<br>• Air quality is monitored by measuring substances such as sulfur dioxide and nitrogen oxides over time.<br>• Carbon dioxide and ozone are monitored worldwide because of their global effects. |
| **3.0**<br>• concentration and dispersal<br>• stability and biodegradability<br>• evidence of toxicity<br>• hazards, probabilities, and risk assessment | **3.0 Potentially harmful substances are spread and concentrated in the environment in various ways.**<br>• Chemical substances are transported through the air, soil, and water.<br>• Substances transported in air are dispersed, diluted, and eventually deposited onto Earth's surface.<br>• Substances may be transported through soil or rock by groundwater, and they can be chemically changed.<br>• Processes such as dispersion, dilution, biodegradation, phytoremediation, and photolysis can change the concentration of chemicals in the environment.<br>• Hazardous materials affect living things. For example, oil spills affect micro-organisms, plants, animals (including humans), and the abiotic environment.<br>• Care must be taken in the use, storage, transport, and disposal of hazardous household goods. Government regulations, such as WHMIS, and new product regulations attempt to protect consumers in the home and in the workplace. |

# Fuel Combustion in Electrical Power Plants

## The Issue

As you read in section 1.0, the need to produce more electricity must be weighed against the environmental impact of more electric power plants. Electric power generation is the third largest producer of sulfur dioxide and nitrogen oxide emissions in Alberta. Mercury emissions from coal-fired power stations are also a concern because mercury harms the human nervous system.

Almost 60% of Alberta's electricity is generated by coal-fired plants. Natural gas-fired plants generate about 33%. Hydro provides most of the rest, with some from wind and biomass. Coal-fired generating plants are built close to coal mines to limit the distance required for coal transportation. Long transmission lines transport the electricity to consumers. Pipelines transport natural gas to natural gas-fired plants.

Suppose that your community is in the process of deciding if an electricity generating plant should be built in your area. There are two options: a coal-fired plant or a natural gas-fired plant.

## Go Further

Now it's your turn. Look into the following resources to help you learn more:

- Look on the Web: Check the Internet for information on generating electricity in Alberta and the benefits and costs of using coal or natural gas. Begin your search at www.pearsoned.ca/scienceinaction.
- Ask the Experts: Try to find an expert on electricity generation, such as an engineer or a planner. Experts can be found various places: the electric company, universities, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about electricity generation.

## Analyze and Address the Issue

Use the information you collected to help you analyze the risks and benefits of each method of electricity generation. Then write a brief report that states your conclusion about the type of fuel that could be used to produce electricity for your community. Give evidence to support your conclusion.

| What people in favour of coal say | What people in favour of natural gas say |
|---|---|
| Coal is plentiful in Alberta. | Natural gas is plentiful in Alberta. |
| Burning coal is less expensive than burning natural gas. Electricity produced by burning natural gas costs much more than electricity produced by burning coal. Also, the price of coal is more stable than the price of natural gas. | A coal-fired plant is much more expensive to construct than a gas-fired plant. Expensive technology is required to remove pollutants from the smokestacks of coal-fired plants. |
| Alberta coal is low in sulfur content. | Natural gas is a cleaner burning fuel than coal because most of the pollutants, such as sulfur and nitrogen compounds, are removed in processing before the gas is burned. |
| New coal-burning technologies are efficient and meet stringent emission regulations. | New technology for co-generation allows the use of natural gas to generate electricity in a more environmentally friendly manner. |

# PROJECT

## A REFINERY MEGA-PROJECT—CONSIDERING THE OPTIONS

### Getting Started

Human activities such as mining, forestry, agriculture, transportation, and wastewater treatment all supply us with needed products and processes, but they all have the potential to produce chemicals that harm the environment.

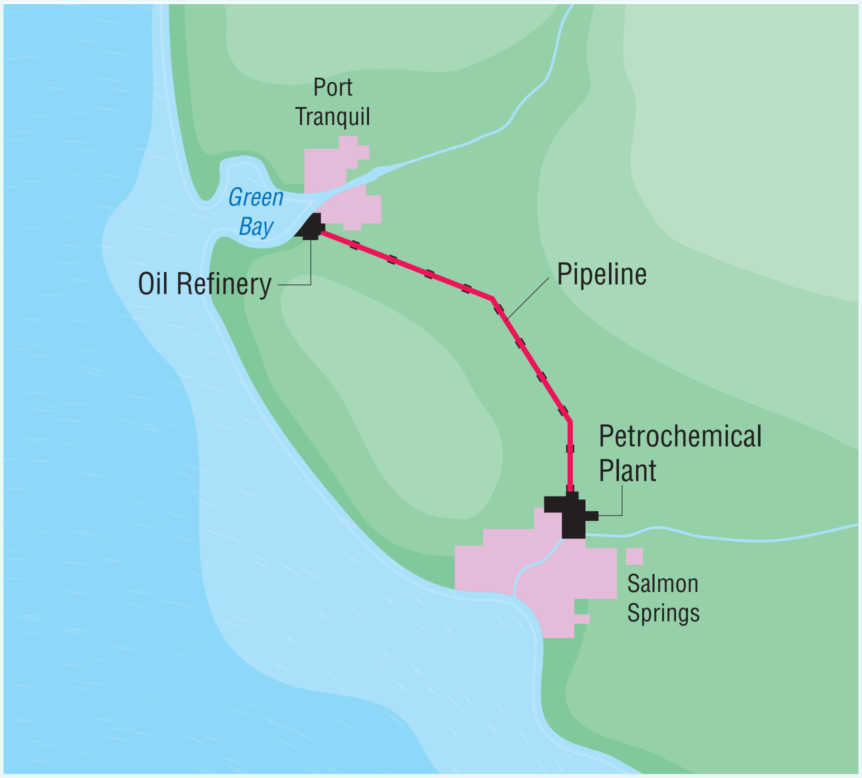
The fictitious community of Port Tranquil is located in Green Bay, an area similar to Alaska's Prince William Sound. It is considering a proposal to build an oil refinery near the port.

### Your Goal

The goal for your class will be to decide whether or not an oil refinery should be built at Port Tranquil. You will work in small groups to prepare for a public hearing. After listening to presentations from people with different points of view, you will make a decision about the building of the oil refinery.

### What You Need to Know

The harbour of Port Tranquil is safe for tanker ships to unload crude oil at the proposed refinery. If the refinery is built, the citizens of Port Tranquil will have access to jobs such as building and operating the refinery and a pipeline to a nearby petrochemical plant. They will also have cheaper heating fuel for homes and gasoline for vehicles. Despite the economic benefits, many people here still remember the environmental problems caused by the *Exxon Valdez* oil spill.




The Port Tranquil area

The town council of Port Tranquil will hold a public hearing on the issue of whether the town should allow an oil refinery to be built. The participants who have registered to speak are:

- A citizen of Port Tranquil who has been looking for employment for six months
- A fishing guide whose main income is from tourists who come to the Green Bay area for salmon fishing
- A developer who owns land near the town that would be suitable for new housing
- An environmentalist who helped clean up the oil spill in Prince William Sound
- An artist who paints natural scenes that include wildlife
- A homeowner who likes the quiet life in Port Tranquil
- The manager of the company planning to build the oil refinery
- Others you may wish to add to the list

### Steps to Success

1. The class will be divided into 10 groups. One group will represent the officials (chairperson, secretary, and assistant) at the public hearing. Another group will represent reporters and photographers. The remaining groups will prepare the two-minute speeches of the registered participants. You may want to dress as the person you will represent at the hearing.
2. The officials will need to plan the following:
   - room arrangement (e.g., seats for speakers at the front of the room)
   - opening remarks made by the chairperson
   - order of the presentations
   - procedure for the question period
   - a way to determine whether the refinery will be built, built with restrictions, or not built (e.g., you could collect the individual decisions made by the students and report the count in the next class period)
3. The reporters and photographers will decide:
   - how to gather information for their news report (TV or newspaper)
   - title, length, and content of their article or report
   - the number and type of photographs needed (if the report will be a newspaper article)
4. The students working on the speeches for the registered participants will decide:
   - if they are writing a speech for or against the building of the oil refinery
   - what to say in a two-minute presentation
   - which member of the group will make the speech at the hearing
5. At the public hearing, the chairperson will call the meeting to order and state its purpose. One of the officials will introduce each speaker. The chairperson will maintain order during the presentations and the question period to make sure no one is interrupted.
6. As each speech is being made, analyze the presentation by filling in an information sheet like the one shown below.

| Speaker | Viewpoint : For/Against/ For with restrictions | Reasons |
|---|---|---|
| | | |

7. If you need to clarify a fact or viewpoint, ask questions during the question period after the last presentation.
8. The chairperson will close the meeting and announce when the decision will be made public.
9. Use your information sheet to help you analyze the risks and benefits of each possible decision about the refinery's construction: for it, against it, or for it with restrictions. You may want to use a chart like the one below to organize the information. After you have analyzed all the options, write down your decision on a piece of paper.

| Risks associated with my decision | Benefits associated with my decision |
|---|---|
| | |

10. The officials will collect the decision sheets and count the results to determine a class decision on whether or not the refinery should be built.

### How Did It Go?

11. What role did or could science play in this decision-making process?
12. What role did or could technology play in this decision-making process?
13. Do you think an individual can make a difference by speaking at a public hearing? Explain your answer.
14. Do you think a public hearing like this is a good way to make decisions about major issues that involve science and technology? Explain your answer.
15. What would you do differently if you had to participate in a hearing like this again?

# UNIT REVIEW: ENVIRONMENTAL CHEMISTRY

## Unit Vocabulary

1. Create a concept map that illustrates the relationships among the following terms. Start your concept map with the words *environmental chemistry*.

   pollution
   fertilizer
   pesticides
   acids
   bases
   organic chemicals
   inorganic chemicals
   dispersion
   dilution
   biodegradation
   groundwater
   monitoring

## Key Concept Review

### 1.0

2. Name three sources that can increase the amounts of the following substances in the atmosphere:
   a) carbon dioxide
   b) sulfur dioxide
   c) nitrogen oxides
3. In what form is nitrogen available for plant use? List three ways that nitrogen is made available for plant use.
4. Describe the difference between an acidic solution and a basic solution.
5. How does acid rain form?
6. How is magnesium used by plants and humans?
7. Explain one difference and one similarity between osmosis and active transport.

### 2.0

8. What biological indicators in a freshwater sample indicate a healthy environment?
9. Explain a possible reason for the recent rise in atmospheric carbon dioxide.
10. Why do governments monitor emissions of sulfur dioxide and nitrogen oxides?
11. Fish are not usually found in water that has a pH below a certain level. What is this pH level?
12. Define the term "heavy metal" and give an example.

### 3.0

13. What are the three phases of atmospheric transport?
14. Explain the difference between the terms "aerobic" and "anaerobic."
15. a) What is groundwater?
    b) Why should it be protected from pollution?
16. Why is it important to know where the MSDSs are located in your school?
17. Why is the transport of chemicals a global concern?

## Connect Your Understanding

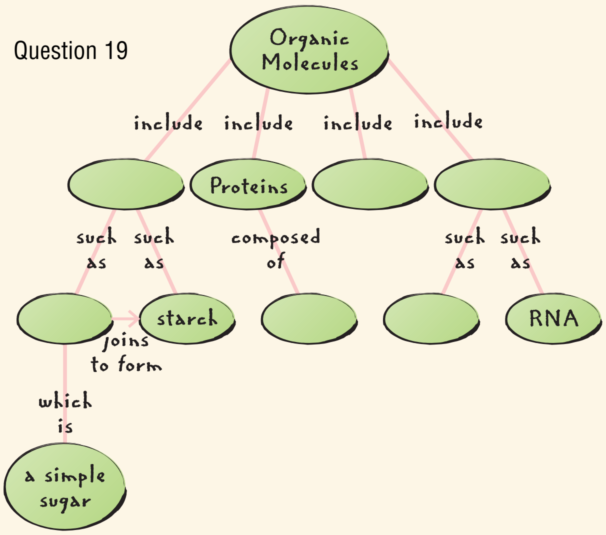
18. a) What is the difference between an organic chemical and an inorganic chemical?
    b) Indicate if the following substances are organic or inorganic:

| | |
|---|---|
| glucose | mercury |
| lead | oxygen |
| amino acids | fertilizer |
| carbon dioxide | crude oil |
| protein | propane |
| lipids (fats) | DNA |

19. Copy the concept map shown here in your notebok. Complete it by placing the terms below in the appropriate places.

| | |
|---|---|
| DNA | carbohydrates |
| lipids | glucose |
| amino acids | nucleic acids |

Question 19




20. Which of the following processes returns carbon to the atmosphere most quickly?
a) decomposition of dead plants and animals
b) photosynthesis
c) formation of oil
d) fuel combustion

21. Explain why the following tests are used to determine water quality.
a) pH
b) dissolved oxygen
c) phosphorus

22. Match a technological process or product with the resource it is meant to protect or conserve.

| Resource | Technological product or process |
|---|---|
| air | smaller, lighter cars |
| soil | fertilizer |
| water | scrubber |
| plants | sewage treatment |
| fossil fuel | insecticide |

23. A solution has an initial pH of 3.5. After it passes through soil, the pH is 5.3. Explain what has occurred.

24. Write a paragraph about cleaning up pollutants in the environment using the following terms:

biodegradation
phytoremediation
accumulation

25. Describe the correct storage and disposal of:
a) gasoline
b) hydrochloric acid (used in toilet and sink cleaners)
c) car batteries
d) leftover paint

26. Read the label shown below and answer the following questions.
a) What precautions should you take when handling a corrosive material like this bleach?
b) Suggest safe ways to store a corrosive substance.
c) Why does the label say that bleach should not be mixed with other household products, especially acids?
d) Name two acidic substances commonly found in homes.
e) Why would it not be a good idea to put undiluted bleach into a septic tank?


Question 26



## Extend Your Understanding

**27.** How does inorganic carbon become available to living things?

**28.** Most people in Alberta have a high standard of living. What pollutants are associated with a high standard of living? Why?

**29.** Using atmospheric carbon dioxide as an example, explain what is meant by "optimum amount." In your answer, identify a problem related to too little carbon dioxide in the atmosphere. Also explain the problems that might arise if there is too much carbon dioxide.

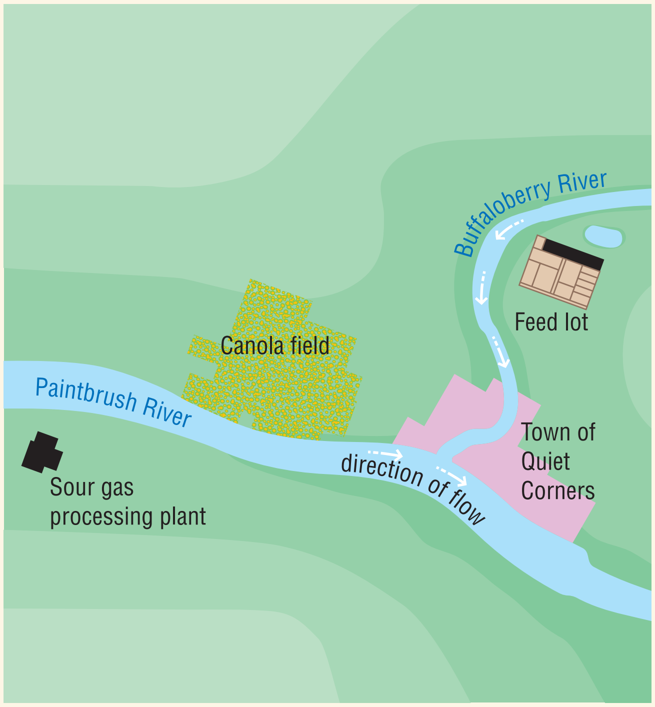
**30.** Suppose that the government passes legislation stating that no release of sulfur dioxide and nitrogen oxides would be permitted.
- a) How do you think this would affect industry?
- b) How do you think it might affect you?

**31.** Imagine that a farmer has tested the soil and found that it is low in nitrogen.
- a) The farmer plans to use a fertilizer to improve the soil. Which of the three numbers on the fertilizer bag should be highest?
- b) A heavy rain falls just after fertilizing is completed. What effect might this have on the availability of nitrogen for the crop?
- c) A neighbouring farmer suggests that the field should be planted in clover (a legume) for one year and then ploughed under before it is used again for a commercial crop. How would that suggestion benefit the soil?

## Practise Your Skills

**32.** Suppose a bag is almost filled with a glucose-water solution. The bag is permeable to water molecules but not to glucose molecules. Predict what would happen if the bag were placed in water. How could you test your prediction?

**33.** Look at the map below. Imagine that you have worked for the town of Quiet Corners for the past 15 years managing the drinking water supply. You notice that this year there has been no large emergence of adult mayflies as there has been in previous summers.
- a) What water tests might help you identify problems?
- b) How might you identify the source of the problem?




Question 33

**34.** Testing has found 0.004 mL of lead in a 1000-mL sample of soil. Calculate the concentration of lead in parts per million.

## Self Assessment

**35.** Think about your work in group activities. Consider the following skills and answer the questions below:
- listening to all suggestions made by your team
- contributing to brainstorming sessions
- being creative
- doing your share of the work
- completing tasks on time

a) What did you do well?
b) What do you need to improve?

**36.** What did you learn in this unit about the role of science in social and environmental issues?

**37.** Describe three ways in which your lifestyle affects the environment.

**38.** What questions or issues about environmental chemistry would you like to explore further?

## Focus On Social and Environmental Context

In this unit, you have investigated the social and environmental context of environmental chemistry. Consider the following questions.

**39.** Re-read the three questions on page 181 about the social and environmental context of environmental chemistry. Use a creative way to demonstrate your understanding of one of these questions.

**40.** Explain two benefits of analyzing different viewpoints when making decisions.

**41.** Use two examples from this unit to explain why it is important to monitor chemical changes in the environment.